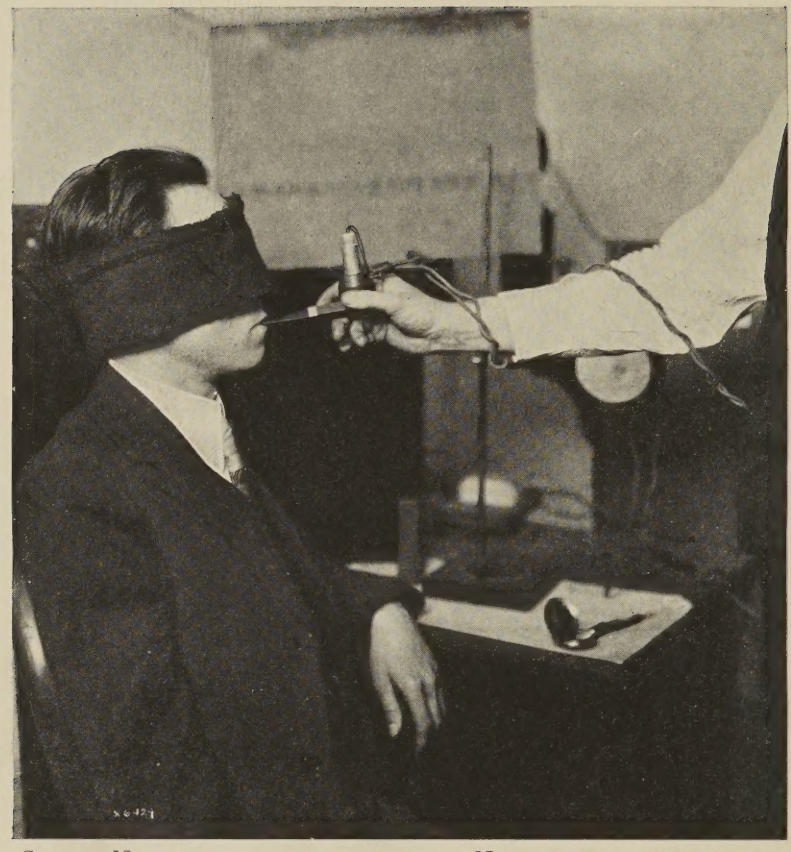

SUBJECT NO. 3 RECEIVING THE CONTROL DOSE. NOTE THE BANDAGE, THE EXPERIMENTAL PIPE AND THE ELECTRIC WIRE WOUND AROUND THE ARM OF THE EXPERIMENTER TO PREVENT DETECTION BY THE SUBJECT.

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The Influence of Tobacco Smoking on Mental and Motor Efficiency

An Experimental Investigation

BY

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Appendix

INTRODUCTORY NOTE

In 1917 the American Committee for the Study of the Tobacco Problem appointed a subcommittee on Educational Aspects, and the writer of this note was made chairman of that committee. After a year or more of preliminary study, it became apparent to him that it would be desirable to broaden the investigation, with a view particularly to making tests in the psychological laboratory to determine if possible by precise measurements the effect of tobacco upon intellectual process. So the writer proposed to the American Committee that the problem assigned to him for investigation should be entitled, "Tobacco and Mental Efficiency," and that an appropriation should be made to defray the expenses of preliminary experimentation for the purpose of attempting to develop suitable technique for the laboratory study of the effect of tobacco on mental activities. The American Committee accepted these suggestions and provided adequate funds for an exploration of the matter in hand. The writer then laid before Dr. Clark L. Hull, Associate Professor of Psychology and Director of the psychological laboratories in the University of Wisconsin, the problem which he wished to have investigated, and asked if he could spend the summer of 1919 in developing a technique for the study of the relation of tobacco to mental efficiency. Dr. Hull consented to do this. The results of the summer's work showed conclusively to Dr. Hull, to the writer and to the American Committee that it was possible to measure the effect of tobacco upon the mental processes with a high degree of accuracy. The writer then secured from the American Committee a generous appropriation of funds for the prosecution of the laboratory investigation, which was placed in charge of Dr. Hull, who was thus enabled to secure subjects and trained assistants in order to carry through the investigation in a thorough-going way. This volume presents the results of the investigation, together with a summary of the results of previous investigations and a discussion of the methods employed to secure reliable data uncomplicated by disturbing factors.

The writer has followed the laboratory investigation throughout with genuine interest, and he is convinced that the data secured and the conclusions reached are of unusual importance. Dr. Hull has succeeded in developing a technique to overcome difficulties in the investigation of the drug effects of tobacco which no previous investigator, so far as the writer knows, has been able to overcome. The report is presented in a concrete, clear, and attractive form, so that it may be read with pleasure and profit by any one who is interested in psychological investigation and also by those who wish to find out for their own information or for the guidance of others whether tobacco exerts any measurable influence upon the intellectual processes.

It should be specially noted that this laboratory study constitutes but one phase of a broader investigation of the relation between tobacco and mental efficiency. Because of the extent and importance of the results of the laboratory investigation, it has been deemed advisable to publish them separately in this volume. Another volume presenting the results and conclusions of the investigation as a whole, and showing the connections between the data derived from the laboratory and from several other sources will be published by the writer, under whose direction the various phases of the investigation have been carried on.

The University of Wisconsin M. V. O'SHEA.
May, 1922.

PREFACE

The circumstances under which the investigation reported in the following pages was carried out, require a brief statement. In May of 1919, Professor M. V. O'Shea of the Department of Education of the University of Wisconsin, stated to the writer that the American Committee for the Study of the Tobacco Problem of which he was a member, had appointed him chairman of a sub-committee which had been created for the purpose of investigating the effects of tobacco on the intellectual processes. In this connection he requested the writer's opinion as to the feasibility of an experimental attack upon the problem. The reply was that the success of such an experiment would depend very largely on whether or not a neutral control dose could be devised which would not be distinguished by the subject from the actual tobacco. As the result of this conference the writer undertook to spend the following summer in determining the practicability of the project.

The first six weeks of this period were consumed in devising and assembling apparatus and tests, and in perfecting the exceedingly delicate technique. During this period three subjects were experimented on in an extensive series of preliminary tests; the numerical results of which were discarded. These preliminary experiments having shown beyond a doubt the feasibility of the neutral control dose and the adequacy of the technique in general, two subjects (1 and 2) of the regular series reported in the following pages, were put through the experiment. A detailed report of the summer's investigation was then made.

Upon the basis of this report, together with Professor O'Shea's recommendation, the American Committee for the Study of the Tobacco Problem made a generous appropriation for the continuation of the investigation, and the writer agreed to see the work through to completion. It was understood that the investigation together with the final report of the fiindings, were to be strictly scientific and impartial, and that the present writer should have the right of publication of the results, regardless of whether they

should turn out to be favorable or unfavorable to tobacco. It was also agreed that an adequate supply of subjects together with a number of trained laboratory and statistical assistants should be provided at the expense of the committee.

The assistants, in addition to a previous thorough training in experimental psychology, were each given special training and instruction in his duties before entering upon them. The writer is glad to take this opportunity of expressing his deep debt of gratitude for the splendid, unselfish service of these people. Without their loyal assistance and cooperation, the enormous labor involved in this investigation could not possibly have been performed. The feeble recognition of their work possible in this place is very inadequate compensation for their weeks, and in some cases months, of most exacting service. Arranged chronologically, their names are:

FRED G. MUELLER
BERTHA IUTZI HULL (Statistician)
COURTNEY SHERMAN
E. A. CULLER
CHESTER H. MATRAVERS
FILIP FORSBECK
EVERETT F. PATTEN

The work of each deserves special mention.

Mr. Mueller conducted the tests on six subjects, a total of over 100 evenings of continuous experimentation. Mr. Mueller also contributed a number of valuable suggestions regarding the technique of the experiment.

Mrs. Hull scored the great mass of test results and made the primary computations, for the greater part of the subjects employed in the investigation.

Mr. Sherman and Mr. Culler each carried one subject through the tests, Mr. Sherman having himself previously served as a subject.

Mr. Matravers carried three subjects through the experiment and did the scoring and primary statistical work on two, after having himself served as a subject.

Mr. Patten gave the tests to three subjects, besides scoring the test results and making the primary computations on four subjects.

The writer wishes to thank the American Committee for the Study of the Tobacco Problem for the most generous grant of funds which alone made the present work possible. In particular, he is under obligation to Professor M. V. O'Shea who, throughout the protracted investigation, has been a source of encouragement and inspiration.

Lastly, thanks are due Dr. W. W. Garner, Director of Tobacco Investigations, U. S. Department of Agriculture, who very kindly made a careful chemical analysis of the tobacco used in the present investigation.

Madison, Wisconsin. CLARK L. HULL
July, 1922.

THE INFLUENCE OF TOBACCO SMOKING ON MENTAL AND MOTOR EFFICIENCY

CHAPTER I

Summary of Previous Investigations

In so far as they relate to the present study, previous investigations of the effects of smoking may be divided into three general groups: a physiological group, a psychological group, and a statistical group. In the interests of clearness of presentation in the following pages, each group will be considered separately.

The studies of the physiological group are all experimental in nature. They report the effects of tobacco on such processes as heart rate, blood pressure, steadiness, precision of voluntary movement, and muscular fatigue.

Several of the writers who have experimented on the influence of tobacco have observed more or less casually that the heart rate was increased after smoking. The problem was investigated systematically in 1914 by J. W. Payne.[1] He used ten subjects of whom six were habitual smokers. These subjects were tested on the average between four and five days each, just before and immediately after smoking a cigar, with an approximately equal number of control days. Several of the subjects smoked cigarettes on additional days. Payne reports a marked tendency to increase of both heart rate and blood pressure, but does not give averages. The present writer has computed from Payne's published data the average net increase of the pulse rate on the tobacco days (Appendix A). It amounts to an increase of 7.98 beats per minute for the horizontal position and 6.94 beats for the vertical or standing position. The cigarette results, while not strictly comparable because incomplete, suggest a stimulation about half as great. Computation of the statistical reliability of the above averages indi-

[1] Fisher and Berry, The Physical Effects of Smoking, pp. 1-43.

cates that there is only one chance in several thousand but that there is a net stimulation on the tobacco days.

Two years later Dowling[2] attempted to determine experimentally the influence of smoking two cigars on the return of the heart rate to normal after exercise. Unfortunately his experiment was set up in such a manner that it could not reveal any disturbance in this function even if present. In addition, his methods of computation are so faulty that his statements of results are also misleading. Fortunately he publishes his original data. A somewhat laborious computation from these data for his habitual-smoker subjects shows (Appendix B) that strenuous jumping after smoking leaves the heart rate between six and seven beats per minute faster, on the average, than similar exercise without smoking. But since, according to Payne's results, we should expect approximately this amount of stimulation from the tobacco alone and regardless of exercise, Dowling's conclusion that tobacco causes the increase in heart rate resulting from exercise to persist longer than normal, is without support. Dowling also claims that the normal pulse of smokers is higher than that of non-smokers. A computation of the reliability of the difference found between the average pulse of his smokers and non-smokers shows, however, that the difference found is no more than ordinary chance might produce.

As to precision of voluntary movement, there is abundant evidence that tobacco smoking markedly reduces it. This matter was investigated experimentally by Blickley in 1915,[3] with 14 subjects. He found that after smoking two cigars there was a marked diminution in precision of tracing a line with a fountain pen between two other lines arranged in a zig-zag course and about two millimeters apart. He found a somewhat smaller loss with the same subjects in lunging at a target with a foil. Unfortunately Blickley's non-smoking days were so complicated by irrelevant exercise of a strenuous nature that his control results are not reliable. Consequently the exact percentages of loss reported by him are not significant, though it is quite evident that the smoking caused a certain amount of loss in efficiency. The following year

[2] Fisher and Berry, op. cit., pp. 43-79.
[3] Fisher and Berry, op. cit., pp. 79-125.

Lang[4] continued the investigation, using eight subjects. The activity chosen was throwing base balls at a target. In this case the control days appear to be reliable though as usual no control dose was used. Lang's subjects show an average net loss in efficiency of 21.5% after smoking one cigar and of 24% after smoking two.

In 1919, Oscar J. Johnson in connection with a psychological investigation,[5] reported two experiments which bear on our present problem. The results of his first experiment are not significant. In his second experiment he tested the influence of smoking a cigar upon accuracy of aiming and steadiness of motor control. The aiming appears to have been done with a stylus at a small hole. Steadiness was measured by holding a stylus within a small hole so as to touch the edge as rarely as possible. He used four subjects who served from one to four days each. Their habits as to smoking are not stated. No control records of any kind were taken. The experiment is consequently inadequate, not only as to control but also as to the number of subjects and particularly the number of tests made on each. He reports after smoking an average increase of contacts (loss of efficiency) in the aiming test of 342% and in the steadiness test, of 192%. While probably no special significance should be attached to the size of the above percentages for reasons pointed out above, it is significant that they agree with the results already examined as to the nature of the effect produced. Johnson also reports a slight loss in the speed of tapping.

The following year (1920) Froeberg[6] published as a part of an experiment mainly psychological in nature, some results as to the influence of smoking a cigar on precision of voluntary movement (coördination), steadiness, and rate of tapping. In this case muscular precision was measured by the distance a stylus could be drawn down a narrow V-shaped slit without touching the side. Froeberg used five non-smokers as subjects and tested them immediately after smoking on eight days. They were also tested on eight control days. This experiment is especially interesting because it contains the first and only attempt recorded in the litera-

[4] Fisher and Berry, op. cit., pp. 126-172.
[5] *Psychological Clinic*, Vol. 12, pp. 132 ff. and 230 ff.
[6] *Journal of Experimental Psychology*, Vol. 3, p. 334 ff.

ture to provide a control dose in tobacco-smoking experimentation. On the control days the subjects smoked just as on the other days except that the smoke first passed through cotton wool before reaching the mouth of the smoker. This was done on the theory that the passage of the smoke through the cotton would remove from it all of its physiologically active constituents, though this may be open to question. The method was abandoned, however, after the third subject, the remaining subjects smoking nothing on the control days. The results from this squad of subjects are therefore a little uncertain in meaning because of the mixed and somewhat questionable nature of the control results. Under these conditions, Froeberg found that muscular precision lost 23.5% in efficiency and steadiness lost over 120%. His results in tapping show a slight increase in efficiency on the tobacco days, though it is too small to be significant.

We find, then, despite certain defects of procedure in some of the experiments, a consistent agreement among the various investigators that the immediate effect of tobacco smoking is to diminish very markedly the precision of voluntary movement. This at least may be regarded as established. With this loss of muscular precision probably goes also an increase in muscular tremor. The results as to rate of tapping are inconclusive.

The first and best study concerning the effect of tobacco on muscular fatigue was reported by Lombard in 1892.[7] The study in question was an extensive investigation of the influence of such factors as hunger, sleep, temperature, barometric pressure, and alcohol. Among other things, he investigated the influence of smoking cigars. The criterion used was the amount of work performed by his middle finger on the weight ergograph. The part of his experiment concerned with tobacco occupied eleven days, four of which were control days. Usually five tests were made each day. On the tobacco days he smoked a cigar just before each test, on the control days he did nothing. The control days average 16.027 kilogrammeters of work whereas the drug days average only

[7] Lombard, Warren P. Some of the Influences which Affect the Power of Voluntary Muscular Contraction. *Journal of Physiology*, 1892, Vol. 13, pp. 1-58. The results of this investigation of the effects on tobacco are found on pp. 44-48.

11.375, which is a decrease of over 29%. The present writer has computed the statistical reliability of this difference (Appendix C), and it appears that it could only happen by pure chance in about one case in a hundred. This is considered a very satisfactory reliability. Unfortunately it is impossible to say with any confidence whether this difference reflects merely a personal peculiarity in Lombard's reaction to the drug, or even whether it was caused by the tobacco at all, since no control dose was used.

Two years later in connection with an extensive investigation of the influence of sugar upon work done with the weight ergograph, Harley considered briefly the influence of cigar smoking.[8] He tested the middle finger of each of his hands a variable number of times each day for five days. Two of these were control days. His results, while suggesting a slight loss in efficiency on the tobacco days, are so variable and so small in number that they are practically without value. The statistical reliability has been computed for Harley's results, both as to amount of work done and as to the length of time before exhaustion (Appendix D). The difference found in the former might have happened by chance in about one case in five, the latter in about two cases in five. Neither is significant.

In 1901, Hough reported a brief experiment on the effect of smoking upon muscular efficiency.[9] As in the two previous studies, this also was incidental to a much larger investigation. Unfortunately he used a spring ergograph which yields a markedly different work or fatigue tracing from that given by the weight ergograph used by the other investigators in this field. Hough publishes the results of only two regular smoking days. From his published tables, the results of four other days were found which may evidently be used as controls. Hough concludes that the tobacco had no influence whatever upon the amount of work performed by him, but that it did have a marked influence in delaying the onset of fatigue. This was shown in his results by the slower fall of the work curve to the "fatigue level." Computation shows (Appendix

[8] Harley, Vaughan. The Value of Sugar and the Effect of Smoking on Muscular Work. *Journal of Physiology*, 1894, Vol. 16, pp. 97-122.

[9] Hough, Theodore. *American Journal of Physiology*, 1901, Vol. 5, pp. 240-266.

E) that there is only about one chance in thirty-three of his obtaining such a difference without some cause for it. But as with Lombard's results we are unable to say whether this was due to the tobacco at all, since no control dose was used. His technique, while otherwise excellent, is so different from Lombard's that a strict comparison of the two findings is impossible.

The last study on tobacco and fatigue was reported by Rivers in 1908 in connection with an extensive investigation chiefly of the influence of alcohol and caffeine.[10] He used two subjects. One had two drug days with three control days and the other had two drug days and two control days. Rivers does not give numerical results but states that the drug days were, upon the whole, slightly less efficient than the control days but no more so than might result from chance.

The evidence as to the influence of tobacco smoking upon muscular fatigue, while suggesting a slight loss in efficiency, is thus seen to be conflicting and generally unsatisfactory. The studies have all been incidental to other investigations and have been based upon an entirely inadequate number of subjects usually working on an entirely inadequate number of days. Moreover, no control dose was used in any of them which makes the results subject to various constant errors of unknown proportions, such as suggestion and the excitement of interest. Even Rivers who has done such excellent service in pointing out the dangers from just such sources in all kinds of drug experimentation, used no control dose in his tobacco experiments. We must therefore reserve decision in this important matter until more adequate experimental evidence is available.

The first significant experiment as to the influence of tobacco on the mental processes was reported by Bush in 1914.[11] He used fifteen subjects, all but two of whom were habitual smokers. These men were each tested five times immediately after fifteen minutes of quiet smoking and five times when reasonably free from the effects of smoking. Unfortunately no regular control tests seem

[10] Rivers, W. H. R. The Influence of Alcohol and Other Drugs on Fatigue, 1908, pp. 112-114.

[11] *New York Medical Journal*, Vol. 94, pp. 519-527.

to have been made on the subject themselves, as was done in so many of the experiments considered above. One subject not of the regular smoking squad was put through the tests as a control subject, however, and the results of the other fifteen were corrected according to his performance. Under these conditions, Bush reports that his subjects as a group show a loss in efficiency on every one of the ten mental tests used, the average loss of the ten tests being about 10%. The various tests together with the average loss on each, follow: Cancellation (A-test and E-test), —17%; free (chain) association, —9%; free association (to nonsense syllables) —8%; free association (to nouns and verbs), —22%; controlled association (opposites) test, —14%; controlled association (genus-species) test, —12%; addition, —9%; subtraction, —7%; memory span (visual presentation), —3%; memory span (auditory presentation, —9%.

In discussing the reliability of Bush's experiment, Froeberg remarks:[12] "In spite of the apparent care with which this investigation was made, there are in it certain defects sufficient to cast serious doubts upon the validity of the results. In the first place the results from the smokers were 'corrected' by those from a normal 'control.' But the results from only one subject averaged as they were from only five experiments, can scarcely be considered sufficiently 'normal' to be used as a standard for the other fifteen." Even had a number of control subjects been used instead of one, the control would have been inadequate. One man can never safely be used as a control for another, since the various factors requiring control are sure to differ more or less from man to man. For this reason the only proper control subject for a man is the man himself. To make matters worse, no control dose was used, which throws the results open to all the pernicious influences of interest, excitement, prejudices, and suggestion. In this connection it is interesting to note that Bush actually threw out the results of certain of his subjects because of their failure to apply themselves "impartially." This is unfortunate, but under such experimental conditions it is difficult to see how an experimenter should be certain that any of his subjects were applying themselves impartially.

[12] Froeberg, op. cit., p. 336.

The next psychological study on the effects of smoking was reported by Charles Scott Berry in 1917.[13] He was his own subject and an habitual smoker. For ten evenings immediately after dinner he smoked a cigar and then tested himself on rate and accuracy of addition. On alternate (control) evenings he spent the corresponding time in conversation or light reading and then added as on the drug evenings. The test was to do fifteen examples in addition, each consisting of ten columns of ten digits each. Berry reports an average advantage for the smoking evenings of 7.7% in speed of addition and an advantage of 4.5% in accuracy. Berry's results are somewhat complicated by practice effects so that they cannot be taken quite at their face value. After correction has been made for practice (Appendix F) there appears to be no difference whatever in accuracy but a remarkably consistent advantage in speed, averaging 6.3% in favor of the tobacco evenings. Computation of the statistical reliability of this difference shows that it could only have come about by chance in one case in several thousand and is therefore extremely reliable. Unfortunately these results represent the reaction of but one subject and no control dose was used even with him. There is the additional possibility that the advantage found on the tobacco evenings was really due to privation or withdrawal effects which might have caused abnormally small scores on the control evenings.

Johnson's experiment (1918) has already been mentioned in connection with the effect of tobacco on the precision of movement. In his second experiment he includes two mental tests: a color naming test and an adding test. In the former the score was the time required to name one hundred colors, in the latter the time required to add the figure seven to one hundred two-place numbers. He reports a loss in efficiency in color naming of 11.5% immediately after smoking and one of 5.3% two hours later. Regarding the effect on adding, he says: "Here we have rather unexpected results, in that the time to add is shortened considerably in most instances" (*i.e.*, after smoking).[14] Johnson's various tabular statements as to the effects on adding, while possibly not

[13] *Psychological Bulletin*, 1917, Vol. 14, pp. 25-28.
[14] Op. cit., p. 231.

entirely consistent, seem to show a slight immediate loss followed by a considerable gain. It is not stated whether the subjects were habitual smokers or not. For reasons pointed out on page 8 the results of this experiment are of uncertain value.

Reference has already been made to Froeberg's work. He reports two experiments, the first of which was described above (p. 8). The results of the psychological part of this experiment are for the most part discordant and indecisive, though the tendency inclines to a loss in efficiency on the tobacco days. Possibly this lack of agreement among the various subjects may be due in part to the mixed nature of the control and to the fact that no normal tests were given before the dose. The second experiment, however, was well planned. Five subjects were used, each being tested on six days immediately before and after a half hour of smoking. On six alternate days the tests were given as usual only the subjects spent the half hour in conversation or light reading. Five psychological tests were used. As might be expected, the results of this experiment are much more consistent, though Froeberg modestly disclaims any statistical reliability for them. The present writer has computed the average percentage effect and the statistical reliability of the averages of the group of subjects for each test (Appendix G). Each of the five tests show an average loss in efficiency after smoking and the statistical reliability of these averages is fairly satisfactory in most cases, in some extremely so. Froeberg's final results are as follows: Memory span for letters, —13.6%; uncontrolled association test, —13.1%; opposites test, —4.2%; adding, —5.9%. In the completion test of the Trabue type, no percentage effect could be computed from the published data but all subjects show a loss and the reliability of the average is high.

Baumberger and Martin[15] report an investigation (1920) of the relative output of light and heavy smokers in a large telegraph office. The work was chiefly sending and receiving Morse code messages. There were seven heavy smokers and five light smokers. Tables are given which show the relative output of the two groups for each hour of the day and for the day as a whole.

[15] *Journal of Industrial Hygiene*, 1920, Vol. 2, pp. 207-214.

Through incorrect methods of computation, Baumberger and Martin conclude that six of these differences are significant. A recomputation of the reliability of these differences (Appendix H) shows that only one hour of the day has a difference three times its probable error. This is the first hour and is in favor of the heavy smokers. The sixth hour has a fair reliability, however, and is in favor of the light smokers. The difference between the two groups for the day as a whole has no significance whatever. The weak statistical reliability of the above results is due mainly to the small number of subjects. As the writers themselves point out, such a study could hardly be conclusive evidence of a causal relation between tobacco and efficiency in any case, because of the possibility that heavy smokers in general may be originally somewhat differently constituted as a class from light smokers because of the influence of selection.

The psychological investigations as to the effects of smoking on the mental processes thus appear for one reason or another to be of such a nature that it is extremely risky to draw any general conclusions from them. Froeberg's results, easily the best of the series, probably furnish some ground for a belief that smoking has a detrimental immediate effect on the mental processes of non-smokers. Possibly Berry's meagre results suggest a stimulating effect on habitual smokers. But we have no guarantee that in any of these experiments the influence of interest, excitement, prejudice and suggestion have been eliminated. Until this is done, the issue must remain in doubt. And these things will never be safely eliminated until there is used a control dose such that the subjects do not know when they have smoked and they have not, just as the subjects of Rivers and of Hollingworth did not know when they had taken caffeine and when they had not.

The investigations considered above have been directed almost entirely to the determination of the immediate effects of smoking. Fairly distinct from this is the problem of the effect on general mental efficiency of long-continued smoking. Obviously this latter problem does not lend itself readily to experimental investigation because of the relatively great length of time over which the drug must act. We accordingly find investigators resorting to statistical

analysis usually of accidentally available data bearing on the general mental efficiency of habitual smokers and comparing these with similar data from non-smokers. The chief interest in these investigations has been the influence of smoking on scholarship in the secondary schools. Accordingly school marks have generally been used as the criterion. A very large number of such studies have been reported.[16] These show with great uniformity that non-smokers receive, on the average, better school marks than smokers. This may be regarded as established. Of these investigations, four stand out from the rest and deserve special mention: that of Seaver (1897);[17] that of Clark (1900);[18] that of Meylan (1910);[19] and that of Pack (1912).[20] Since Meylan's investigation was reported with more care and insight than the others and illustrates both the weaknesses and possibilities of this method of approach, it alone will be examined.

Dr. Meylan investigated 115 smokers and 108 non-smokers in Columbia University. He found some slight physical differences between the two groups but much less than were reported by Seaver. Extending his investigation to university marks, however, he found a very striking difference. Over a period of two years the average mark of the non-smokers was 69% while that of the smokers was 62%. The same tendency was shown by the fact that there were only 4% of failures among the non-smokers as against 10% among the smokers. It became evident, however, that other factors besides smoking were probably contributing to produce these differences. Investigation showed, for example, that the 66 fraternity men involved in the investigation averaged only 59.1% as against 68.9 for the non-fraternity men, while the non-fraternity men made up the great bulk of the non-smokers. This raised the question as to whether fraternity life might not be the causal or at least selective factor, rather than tobacco? It was also found that the athletes of the group averaged only 63.2% while the non-athletes averaged 68.3%, and that the athletes were much more

[16] Bruce Fink, Tobacco, 1915. The Abington Press, New York.
[17] *The Arena,* 1897, Vol. 17, pp. 470-477.
[18] *The Clark College Record,* 1900, pp. 91-98.
[19] *Popular Science Monthly,* 1910, Vol. 77, pp. 170-177.
[20] *Popular Science Monthly,* 1912, Vol. 81, pp. 336-344.

apt to be both smokers and fraternity men. This raised the question as to how much of the difference found between the smokers and the non-smokers was in reality due to engrossment in athletics on the part of the smokers? After tabulating these complex data in various ways, Meylan finally concluded that while bad scholarship is distinctly associated with smoking, it is also distinctly associated with athletics and fraternities and that it is impossible to tell how much, if any, of the bad scholarship associated with tobacco was really caused by it. The effect of smoking on scholarhip is thus left undetermined though Meylan deserves much credit for clearly recognizing the extremely complex nature and uncertain meaning of such data.

Had he been acquainted with modern methods of statistical analysis, Meylan need not have left his problem in quite such an unsatisfactory state. As a matter of fact there are well recognized methods which have been derived by mathematicians for the treatment of just such data. Unfortunately they seem not to have been utilized in a single one of the many studies of this kind that abound in the literature. The result is that the problem of the effect of smoking on scholarship is little if any more nearly solved today than it was thirty years ago. In the case of Meylan's investigation, the necessary computations may still be made from his published data. These computations have been performed by the present writer and appear in Appendix I. It will be recalled that the difference in average mark between smokers and non-smokers is 7 points. The computations in question show that when the influence of athletics is removed this difference suffers a slight reduction. When, in addition, the influence of fraternities is removed, it shrinks to only 3.4 points or less than half its original size. Meylan's data, unfortunately, do not permit us to see what would have resulted from still further elimination of complicating factors. It should be noted, however, that the above results, while interesting as an illustration of method, have no special significance as to the actual effect of smoking on scholarship. The probable error is very large with such a small number of subjects and especially by the only method of computation available. For such results to have any considerable reliability there should be 1600 or 2000 subjects.

Moreover, since the inductive method by which the causal relation is sought to be proven involves the principles of residues, certainty can only be established when all other possible factors influencing grades have been eliminated in the manner that athletics and fraternities were above. One thinks at once of such obvious factors as shows, pool halls, gambling, drinking, and especially original differences in native intellectual endowment and temperament. In all investigations of this kind therefore, errors due to native individual differences between smokers and non-smokers should be eliminated by securing the school marks of each subject *before* he began to smoke as well as after.

It should also be emphasized that in all investigations of this character involving a considerable questionnaire element with its characteristic dangers of miscarriage, a carefully planned control should be carried out. The material for such a control may be secured by including in the questionnaire, provision for securing data on one or two variables involving correlations already well known. The reliability of the tobacco data obtained by the questionnaire may then be judged to a considerable extent by whether or not it yields accurate results on these control variables of known correlation. We might, for example, record along with the facts of primary interest, whether each subject's eyes were light or dark and the same with respect to his hair. If, then, the final computations should show no higher correlation between deterioration of scholarship and smoking than between the former and the accidental factor of eye or hair color, say, we may presumably regard the tobacco correlation as negligible. On the other hand color of eyes and of hair should show a high correlation between themselves. If the questionnaire results fail to yield such a correlation, we must assume something seriously wrong with the data and the results of the entire questionnaire immediately fall under suspicion. In short, data which either yields a correlation where there is known to be little or none, or which fail to yield a correlation where one is known to exist, cannot be trusted as a guide to action.

PLATE I. General view of the smoking laboratory. The subjects occupied the chair at the right for the tremor and tapping tests, the chair at the left for all the other tests, and while smoking.

CHAPTER II

The Problem and Methods of Investigation

The experience of Hollingworth and others has shown that a comprehensive investigation of the effects of a drug on the mental processes is hardly within the power of a single individual. In the present case, even with a number of trained laboratory and statistical assistants, it was found impossible to investigate many ramifications of the subject. The problem finally settled upon was: *to determine quantitatively the effect upon the effiiency of a dozen typical mental and neuro-muscular functions of young men, of smoking a large pipe of mild tobacco for a period of 25 minutes, the smoking to take place 1½ hours after a meal, the smoke to be blown from the mouth at once and not inhaled, and the effects to be traced for a maximum of 1 hour and 45 minutes after the smoking ceased.* The problem naturally divides itself into four main parts:

1. The effect on non-smokers who have a gastric tolerance for the drug.
2. The effect upon habitual smokers.
3. The relative rate of recovery of the various mental and motor functions from the effects of smoking.
4. The degree to which habituation establishes a tolerance for tobacco with respect to the various forms of behavior investigated.

The experimental work was performed in the psychological laboratory of the University of Wisconsin. A room 12x18 feet in size was set apart as a special smoking laboratory and fitted up with all the necessary apparatus (Plate 1). the lighting was arranged with care so as to give the subject good illumination yet avoid glare. Special effort was made to eliminate all distraction of the subject's attention by noise. This was accomplished with the most of the subjects by carrying on the experiment during the evening when the psychological laboratory was deserted. Three of the subjects worked afternoons, but during the summer when the general laboratory was not in use.

Nineteen subjects were used in the investigation.[1] Males were chosen rather than females because the greater part of the smoking of the world is done by men.[2] Young adults were chosen because they make more reliable subjects than boys or older men. They were also more easily secured. The relatively narrow range in the ages of the subjects, in conformity with the principle of uniformity of experimental conditions, was intended to promote consistency of results and ease of interpretation. As to previous smoking habits, two distinct groups of subjects were used.[3] The first group was composed of nine men who were either occasional smokers or abstainers, but who possessed a tolerance for tobacco in the sense that smoking ordinarily did not nauseate them. The second group of subjects were composed of nine habitual and rather heavy smokers. All but two of these were pipe smokers. One other smoker subject was employed but his results could not be used for reasons given on p. 31. A summary of important personal data for the various subjects is given in Table I.

The program with each subject was experimentation for 3 hours per day for 18 consecutive days, regardless of Sundays or holidays. It was felt that eighteen days ought to yield a fairly reliable sample of a given man's behavior. It would have been extremely difficult, on the other hand, to secure subjects for a much longer period under such exacting conditions as were imposed. Four of the subjects for one reason or another, were unable to complete the entire 18 days as it was. The experiment with each subject was run without interruption through this rather long period with the purpose of reducing as much as possible the variability of behavior from one day to another. It has been the experience of experimen-

[1] Besides the nineteen subjects mentioned, three other subjects were run in an extensive preliminary series of experiments, during which the technique was perfected. These results were thrown out.

[2] Plans were made at one time to run a squad of young women subjects but they had to be abandoned because of lack of time and funds.

[3] The importance of considering the previous smoking habits of subjects has not always been sufficiently realized. It seems possible that some of the apparent conflicts between the results obtained by different experimenters in this field may be attributed to disregard of this important factor.

talists that variability of reactions are less on consecutive days than where work is intermittent.[4]

The tobacco employed in the experiment was one of the most widely used brands for pipe smoking and was uniform throughout. It is manufactured in North Carolina and is apparently a domestic tobacco of southern growth. It does not ordinarily bite the tongue and is regarded by smokers as a mild tobacco. The exact chemical constitution of the tobacco used is shown in the following table, for which the writer is indebted to Dr. W. W. Garner, Director of Tobacco Investigations of the U.S. Department of Agriculture, who made the analysis at the conclusion of the investigation:

(1¾ oz. sealed tin. Factory No. 256, Dist. of N.C.)

Moisture		9.51%
Nicotine		1.60%
Crude Ash		15.64%
Water Soluble Ash	5.73%	
Water Insoluble Ash	9.91%	
Alkalinity of Ash (Basis of one gram of tobacco in terms of c.c. N/10 acid):		
Soluble Alkalinity		5.44 c.c.
Insoluble Alkalinity		17.44 c.c.
Sugar (calculated as invert sugar):		
Reducing Sugars		6.62%
Total Sugars, after inversion		13.63%
Increase in reducing sugars by acid hydrolosis, calculated as sucrose		6.66%

Dr. Garner adds the following comment upon his examination of the tobacco: "With reference to ash content, the total crude ash comes within the limits to be expected of tobacco of the types probably forming the larger portion of this product; namely, White Burley and bright flue-cured. The purpose of distinguishing between soluble and insoluble ash and the alkalinity of the two portions is to arrive at an approximation of relative proportion of lime and potash salts and the content of organic acids of the origi-

[4] Walter R. Miles, Effect of Alcohol on Psycho-Physiological Functions, p. 30, note.

nal product. The alkalinity of the ash affords a rough measure of organic acids present in the original product. The data obtained are within the range to be expected from a mixture of this character. With reference to the sugar content, the flue-cured type normally contains rather high percentages, say, 10 to 15 per cent, while Burley ordinarily contains much less sugar. The figures obtained might well be expected and do not seem necessarily to indicate any considerable addition of sugar in the process of manufacture."

The dose was 25 minutes of smoking, three full puffs in immediate succession being taken every 20 seconds. The smoke was immediately blown from the mouth and never inhaled. Care was also taken not to swallow any of the saliva while smoking or for some time after. The tobacco actually consumed amounted to approximately 5 grams, moist weight as taken from the tin. The pipe used was a rather large one. The bowl was 2 centimeters in diameter at the top (inside measurement) 3.9 centimeters deep, and had a capacity of 9.2 cubic centimeters when somewhat caked. The tobacco was packed down rather firmly into the bowl and almost invariably lasted through the 25-minute smoking period without refilling. Usually there was left a small quantity of unsmoked tobacco in the bottom of the bowl at the end of the period. The stem of the pipe was of ordinary hard rubber with a hole 3.4 millimeters in diameter.

In modern drug experimentation, inseparably connected with the dose is the troublesome yet insistent matter of the control dose. Rivers' classical statement of this problem is so apt that we may follow Hollingworth in quoting it.

"I can now pass to a feature of method. . . . designed to eliminate the influence of certain psychical factors which have undoubtedly been allowed to affect the results of nearly all who have experimented on the action of drugs. Many of these workers have considered the possibility that their results may have been influenced by suggestion, or of bias towards results which were to be expected theoretically, and some have shown that effects similar to those following the administration of a drug may be the consequence of the administration of a wholly inactive substance which

TABLE I

Personal data concerning the subjects used in the experiment

Subject No.	No .of Days	Group	Age	Status	Previous smoking habits
1	12	Non-Smoker	25	Graduate Student	One or two cigarettes per month
2	12	"	22	Junior Letters & Science	Total abstainer
3	18	"	30	Graduate Student	Smoked cigarettes occasionally while in the army, rarely since.
4	18	"	22	Junior Letters & Science	One cigar per week
5	18	"	27	Senior Letters & Science	Smoked regularly from age 10 to 17. Hasn't smoked at all during last three years.
6	18	"	26	Senior Letters & Science	Total abstainer
7	18	"	27	Junior Letters & Science	Total abstainer
8	18	"	19	Sophomore Letters & Science	Smoked cigarettes a little when about 14 years old, nothing since.
9	18	"	22	Sophomore Commerce Course	Smoked about 20 cigarettes in his life, none within the last five years.
10	18	Smoker	33	Graduate Student	Began smoking at about 17. At present smokes about 3 cigars per day and a pipe occasionally.
11	13	"	28	Music Student	Was in the habit of alternating between pipe and cigarettes, smoking each exclusively for a week or two. Smoked four or five times per day. Inhales.
12	18	"	23	Junior Letters & Science	Smokes numerous cigarettes per day and also a pipe.
13	18	"	24	Senior in Agriculture	Smokes pipe after each meal and evenings while studying.
15	18	"	28	Senior Law Student	Has smoked a pipe for about seven years. Smokes about 5 pipes of Velvet per day.
16	16	"	24	Junior in Agriculture	Has smoked a pipe habitually for last 5 or 6 years. Smokes 6 or 7 pipes per day.
17	18	"	21	Sophomore Medical Student	Smokes 3 pipes of Velvet or Tuxedo per day and about one cigarette. Has smoked habitually for 4 years.
18	18	"	24	Junior in Agriculture	Has smoked regularly for about 4 years. Now smokes about 3 pipes and 4 cigarettes per day.
19	18	"	25	Sophomore Letters & Science	Has smoked regularly for about 7 years except for 1 year due to the objection of his father. Smokes about 5 pipes per day of Prince Albert or Edgworth.

is supposed by the subject to be the drug in question. Few, however, have adopted the obvious precautions which such considerations suggest; Schumberg and Sobieranski are the only workers with drugs who have used any kind of control-substances, and even they do not make it clear that the control mixtures or injections they use were entirely indistinguishable from those containing the active substances.

"The factor which previous writers have considered under the title of 'suggestion' is far from being the only source of error in work on the action of drugs. Féré has shown that the sensory stimulation involved in the act of taking a drug into the mouth and swallowing it may have a very decided effect on the amount of work executed with the ergograph, but even this knowledge did not lead him to adopt any control in his numerous researches on drugs.

"There is, however, another factor which is probably more important than either sensory stimulation or suggestion—viz., the interest and excitement produced by taking a substance when the discovery of its effect is the motive of the whole experiment. . . . Any novelty in the course of an experiment may have a very decided effect on the amount of work. The interest of a conversation, the knowledge that the performance is being watched. . . . or any other variation in the routine of the daily experiment, may have very obvious effects on the amount of work. Similarly, the knowledge that it is the first or last day of an experiment may produce a distinct increase in the amount of work, so decided that I now always adopt the procedure of working for one or two days before and after the period which is to provide the proper data for the experiment.

"If such a condition of interest as that arising from its being the first or last day of an experiment. . . . can have very appreciable effects on the amount of work, it is clear that so interesting an occurrence as the administration of a drug must have a decided influence." (Rivers, "The Influence of Alcohol and other Drugs on Fatigue," pp. 18-19.)

It is easy to show that without an adequate control, the results of tobacco experimentation may be almost meaningless. In one

series of observations, the pulse of nine smokers was taken systematically over a period of about 230 experimental hours. Each subject's pulse was taken (sitting) upon his first entering the laboratory. After sitting quietly for 15 minutes, it was taken again. Then followed about 30 minutes of mental testing including five minutes of continuous addition, after which the pulse was again taken. Then came 25 minutes of smoking after which the pulse was taken a fourth time. Following this the mental tests were repeated three times more, after each of which the pulse was taken, making seven times in all. The last pulse was taken about 1 hour and 45 minutes after the conclusion of the smoking. The results of all nine subjects averaged together are shown graphically in Fig. 1. This curve shows a marked rise immediately after the dose. The question at one presents itself as to how much of this increase is due to the tobacco and how much to other factors? How much, for example, would the heart rate have increased merely as the result of the subjects' puffing on the pipe, their expectation of some kind of an effect taking place and the interest and excitement of having the effect measured? We can not tell. Thirty-five minutes later the situation is even worse. It is impossible at this point to judge whether the tobacco has produced any effect whatever, to say nothing of how much. The pulse *appears* to have returned to normal. Again, at the end of the experimental day, the same ambiguity exists, though here the great fall in the curve suggests that the initial stimulation of the heart rate may have given place to a depression. The interpretation of the curve is thus largely a matter of conjecture. These data can only have value for scientific purposes when we know what *would* have been the heart rate throughout, had all other factors both physical and psychological been strictly the same except that no tobacco was taken into the body. This obviously can be brought about only by the use of a satisfactory control dose.

Since the work of Rivers, the above principles have been generally recognized by psychologists. Nevertheless, Rivers himself conducted an experiment on the effects of smoking without any control dose whatever. The reason appears in his rmark, "Any kind

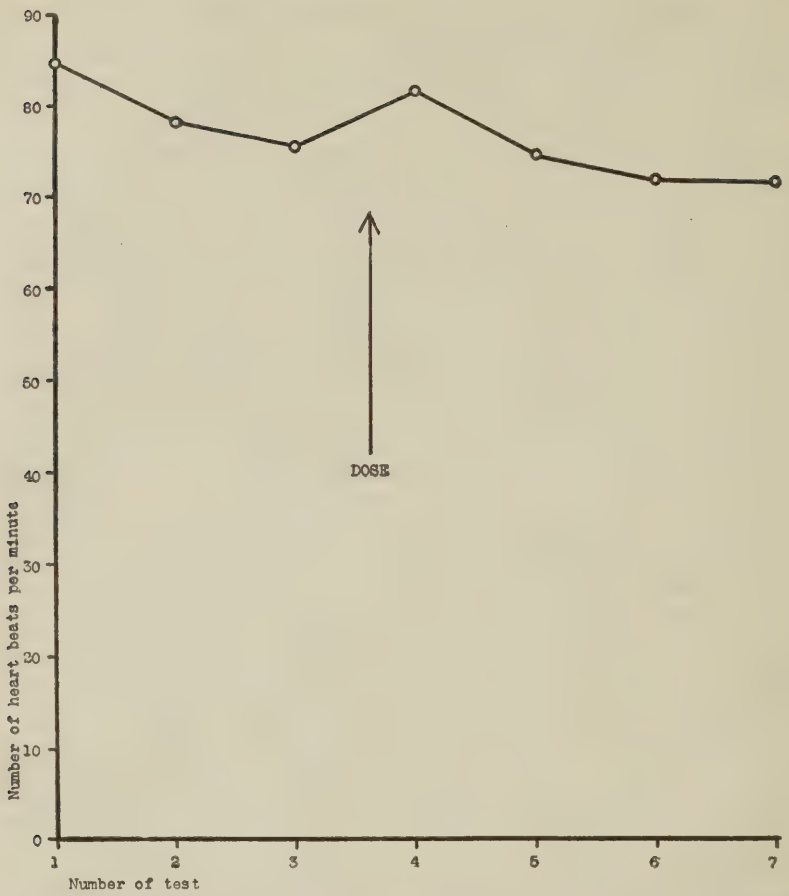

FIG. 1. The average heart rate of a group of habitual smokers at various periods before and after smoking.

of a disguise was of course impossible."[5] Johnson came to the same conclusion ten years later. He says, "Unlike other experiments on the effects of drugs, it was impossible to disguise the taking of it into the body."[6] Froeberg, indeed, attempted a control dose but abandoned it. This particular defect in the technique of previous investigators thus appears to have been due largely to the supposed impossibility of providing a satisfactory control dose.

[5] Op. cit., p. 114.
[6] Op. cit., p. 139.

Fortunately it was found possible in the present investigation to surmount this difficulty. After some preliminary experimentation, a very satisfactory control dose was devised, though its use demanded some skill and deftness on the part of the experimenter. Indeed the success of the control depended as much upon the method of use as upon the nature of the device itself. The first and most important consideration of method was that the subjects were never given the least inkling that a control dose was to be used.[7] To this end it was necessary deliberately to mislead them to a certain extent, as to the real nature of the technique. In a series of two preliminary talks in which each subject was given his general instructions, it was explained among other things that the effects of the tobacco upon mental efficiency would be shown by the difference between the scores on the tests before and after smoking. This seems quite logical to the layman. Accordingly (it was explained) it was imperative that the subject should give the same conscientious application to the mental tests throughout the experimental period. It was pointed out with great earnestness that the success of the entire undertaking depended upon this. If, for example, there should be any letting down of the subject's efforts after smoking (it was explained), this would decrease the score at that point and would falsely be taken as an evil effect of the tobacco, thus completely invalidating the experiment.[8] To emphasize this still further, before each subject was engaged, a solemn promise was exacted from him to keep up throughout the experiment the maximum effort that could consistently be maintained. The great earnestness with which this "coaching" was done seems to have had much to do with the success of the control dose.

Moreover, the technique of the smoking itself was designed in

[7] The importance of this factor can scarcely be overestimated. Some drug investigators seem to have overlooked it entirely and their subjects appear to have been constantly on the alert to see if they could not detect the control. Nothing could be more unpsychological. The present device would probably have failed completely under such conditions.

[8] While such a method of experimentation as described to the subjects would have been without scientific value, it was not so very different from some actual drug experiments that have been reported. Only one subject of the nineteen saw through the deception. His results were thrown out for this reason. (See note, p. 31.)

part to facilitate the use of the control. On approximately half of the experimental days (which always included the first two of each man's series) the subjects smoked the regular tobacco in a regular pipe, blindfolded. The preliminary talks had prepared the subjects for a very elaborate technique, and the blindfolding caused no surprise. After the experimenter had filled the pipe in preparation for lighting on the first day with a given subject, he explained to the man in a somewhat technical manner, that there was some scientific reason to believe that even the sight of the smoke might have an influence on the results entirely apart from any physiological effect the tobacco itself might have. This (it was explained) would obviously spoil the experiment. He was therefore asked to close his eyes and keep them closed throughout the smoking period. After the subject's eyes were closed, the experimenter casually added, "In order that you shouldn't forget at any time, I'll just put this over your eyes to prevent any accident." With this he quietly adjusted over the subject's eyes a heavy blindfold specially provided with pads to fit either side of the nose. The necessity of exactly timing the puffs was also explained. Owing to the subject's inability to see the watch, the experimenter handled the pipe, putting it to the subject's lips for three puffs every 20 seconds.

On the remaining experimental days but entirely unsuspected by the subjects, the regular tobacco pipe was replaced by a special experimental pipe. The second pipe was originally an exact duplicate of the first. (Plate 2). In its bowl was installed an aluminum capsule with walls two millimeters in thickness. The top of the capsule projected three centimeters above the wood of the bowl. In the bottom of the capsule was placed some porous asbestos plaster through which a small hole led downward through the capsule itself to near the opening which leads out to the stem of the pipe. Above the plaster and resting in a cup-shaped depression of the latter, were two concentric asbestos insulating tubes, the outside diameters of which were 1 centimeter and .35 centimeter respectively.[9] Between these tubes was a coil of 25 turns of nicrome electric

[9] The asbestos tubes were made by moistening rather liberally a piece of thin asbestos paper of proper dimensions and wrapping this about a smooth round metal rod of suitable size. The wrapping was done by rolling the rod over the

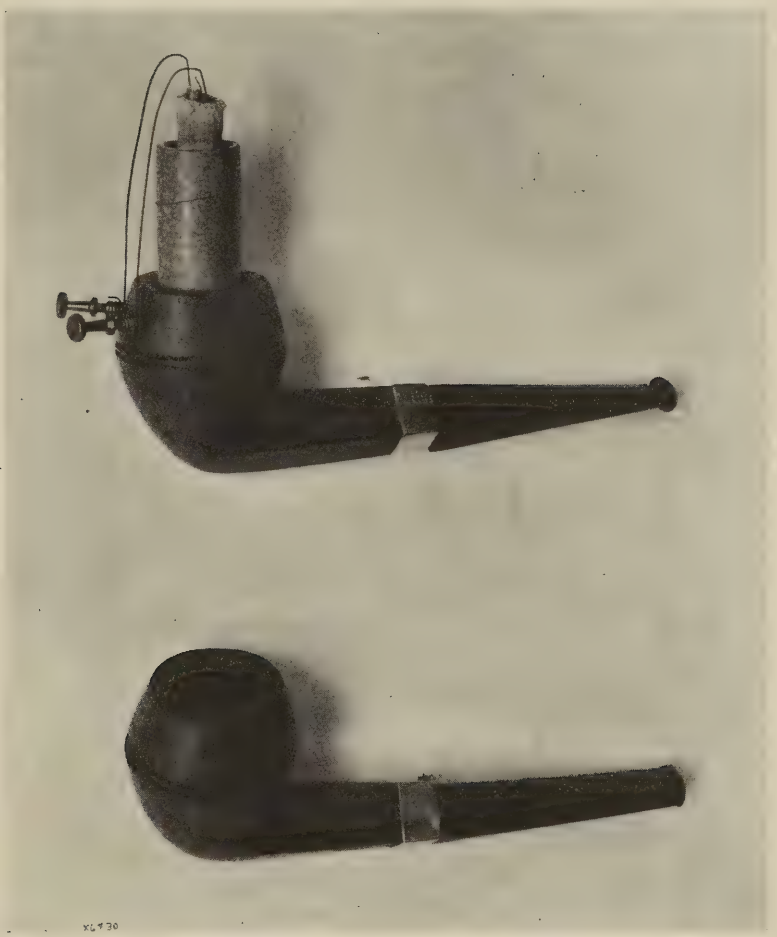

PLATE 2. The special experimental pipe (above) and the regular tobacco pipe (below). Note the exact similarity in form of the two pipes.

heating wire, ½ millimeter in diameter. The wire from the lower end of the coil returned upward within the smaller insulating tube. The two ends of the wire, well apart, now arched upward from the tubes, over the edge of the capsule and thence downward, each to a separate binding post screwed into the bowl of the pipe. (Plate 3). A direct current of suitable size was led to these posts by flexible lamp cord, from a rheostat receiving 110 volts. A few

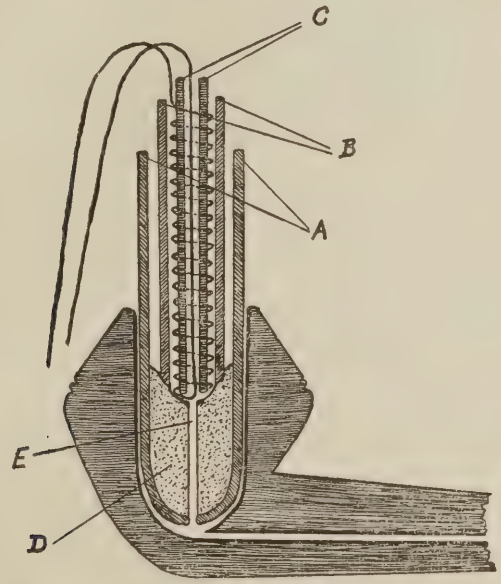

PLATE 3. Diagram of experimental pipe. *A*, aluminum capsule; *B*, outer asbestos tube; *C*, inner asbestos tube; *D*, plaster moistened with water; *E*, hole through moistened plaster through which heated air passes.

drops of water placed carefully on the asbestos plaster about two hours before use so as to be thoroughly absorbed, completed the device.

The warm, slightly moistened air obtained by the subject from this experimental pipe, then, furnished the basis for the illusion.

paper (once one edge of the paper is made to adhere to the rod) with a heavy downward pressure. After heating a short time while still on the rod, the tube becomes very firm if sufficiently wet before heating. The paper used by the writer was made by himself from asbestos fibres washed from some asbestos plaster and dried in a thin layer.

The temperature of the air could be controlled at will by the experimenter through the adjustment of the rheostat. In addition, the resistance to suction as well as the sound of the air being drawn through the device, were carefully adjusted by means of asbestos fibre, to duplicate the corresponding aspects of actual smoking. The feeling of the stem in the mouth was an exact duplicate. Near by but unknown to the subject, the experimenter himself smoked more or less on the real pipe and with the real tobacco, thus furnishing the indispensable odor.[10] And since there probably is no taste in tobacco smoke[11] the only factor of the normal smoking complex lacking, is the occasional slight bite of the tobacco on the tongue. A little excess heat easily furnished this last necessary element of pain.

In addition to the above synthetic duplication of the sensory experience of smoking, the whole thing was powerfully reinforced by normal suggestion. When the subject took his place in the smoking laboratory, he saw the familiar (regular) pipe, tobacco, and matches in their usual places. A quantity of strong-smelling charred tobacco from previous smokes was strewn about on the table in an untidy but extremely suggestive manner. Before the dose on the control days, the experimenter would elaborately (but without remark) clean out the real pipe in the subject's presence, thus furnishing him with an explanation should he notice any difference in the "strength" of the pipe on that day. After being blindfolded, he heard the tapping of the tin, and other incidentals to the filling of the pipe, the striking of the match and the fragance of freshly lighted tobacco came to his nostrils exactly as on the tobacco days. And when the smoking was over, he saw the charred remains of the tobacco in the real pipe (which unkown to him the experimenter had been smoking) there before his eyes. Even the details such as the steps taken and pauses made by the experimenter in securing the experimental pipe from its hiding place, the attach-

[10] This was often discontinued in the latter part of a given smoking period as the olfactory organs grow insensitive to an odor after it has continued for some time.

[11] For the benefit of the non-technical reader, it may be stated that we are able to taste only sweet, sour, bitter and salt. The rich variety of flavors in foods and tobaccos are due chiefly to smell.

ing of the electrical connections and so on, were also gone through with on the tobacco days so that there should be no avoidable difference whatever between the control and the tobacco days. On the top of all, the subject's attention was diverted from the smoking on all days alike by gossipy conversation.

Under these conditions, confirmed smokers would puff the warm air with apparent satisfaction and even (as in one case) serenely go through the motions of blowing smoke rings! In a number of cases where the attempt was made at the conclusion of a series, it was actually found difficult to persuade subjects verbally that they had not been smoking on every experimental day. When shown the experimental pipe they could hardly believe their eyes and declared that after they knew what it was, it did not "taste" the same as it had a minute or two before when they did not know. In the course of the introspections taken at the conclusion of each subject's series, practically all of the eighteen subjects stated positively that even though they were blindfolded and could not see the smoke, they could tell the pipe was lit because they could *feel* the "smoke" in their mouths on every one of the experimental days. Nearly all of them stated further that it would be impossible to persuade them to the contrary.[12] We have here, in short, a repetition of the psychology of the man smoking in the dark who doesn't know that the pipe has gone out. Indeed this was the clue upon which the method was originally based.

The adequacy of the control dose was regarded as of such fundamental importance that a very careful introspection on this point was obtained from each subject at the close of his part of the experiment. The introspection was taken down by the present writer in long hand, then read to the subject for the correction of any errors, after which is was signed by the subject and filed. These documents not only attest the perfection of the illusion produced by the control dose but also yield extremely interesting suggestions as to the general psychology of the attractiveness of smok-

[12] One subject (No. 14) grew suspicious and on one of the control days early in his experimental series removed his blindfold and probably saw the experimental pipe. Thereafter the control dose failed to deceive him and his results were accordingly thrown out. They are given in Appendix J.

ing. A characteristic one is that of subject No. 12, habitual smoker:—

S (subject) thinks that if he inhaled the smoke, there wouldn't have been any difference in the laboratory from ordinary pipe smoking. As it was, the only way he could tell he was smoking was by the gradual increase in the strength of the smoke and the bite on his tongue. S sometimes told he was smoking by the smell but usually does not smell tobacco much. S was able to tell at all times that he was smoking. There were several times that he could not tell whether the pipe was going or not. Such periods were for three or four puffs. S was always sure he was smoking the most of the time on every evening. *There was never any evening when he could have been persuaded that he had not been smoking at last ninety-five per cent of the time.* S thought that some nights there was little or no stinging on the tongue. On such nights he told by the flavor. The last night of the experiment (a tobacco night) it was so strong S did not like it. It bit his tongue and it was an effort to take another pull. The night before, however (a control night) it was fairly good. It didn't bite the tongue to any great extent, not enough to bother much. *It would be an easy matter for S to break off smoking if it were always like the last night.* S enjoyed it the night before. It wasn't strong at all. It tasted fairly well and took the place of not being able to inhale. *S thinks it would be pretty hard to quit under such* (control) *conditions.* (*Signed*) A. M. G.

The above introspection is particularly striking in that it shows a smoker preferring the control dose of warm moist air to the genuine tobacco and feeling that it increased the strength of the habit! The next introspection, that of subject No. 15, habitual smoker, is given because it is the only case where a real doubt entered the mind of the subject. It will be observed that this doubt was a sort of after thought as shown by the somewhat contradictory statement following the second italics. This statement was brought out by a definite question as to whether it would be possible to persuade him that he had not been smoking on any of the nights:—

S always felt rather hungry for a smoke when he first came to the laboratory. *But after the smoke in the laboratory he was always satisfied.* S says that he did not enjoy the smoking, though, when it was going on. This was probably because he couldn't see or handle the pipe. It was given to him slower than he was accustomed

to taking it. S thinks it very difficult to tell while blindfolded whether he is smoking or not. S has wondered lots of times whether the pipe wasn't pretty near out. These periods were for three or four minutes. But this can't be true because he heard experimenter light the pipe. *There was never any night when S was in doubt as to whether the pipe was lit throughout the evening as a whole.* S thinks that on one evening one might persuade him that the pipe was not lit. S never wondered about the matter except this one night. (*Signed*) G. W. M.

A third introspection will be given as typical of the non-smokers. This is from subject No. 7. This subject was somewhat apprehensive about entering upon the experiment because of fear that he might acquire the smoking habit against his will. He was therefore on the alert for any symptoms of habit formation. Thus came about the extremely curious observation of the habit-forming tendencies (under the influence of suggestion) of "smoking" warm moist air.

On some of the nights when it was not very strong S rather liked the smoking. This was strongly apparent about the eleventh day. *On this day* (evidently a control day) *S felt that if he had not moral prejudice against smoking that he would rather like to do it voluntarily.* This grew slightly stronger until the end of the experiment. Last night (a control night) it was best of all. *S feels that such satisfaction as last night constitutes a real habit but not too strong to be overcome.* Tonight, however (a tobacco night) he did not enjoy it and would not have smoked by preference.

S was always sure that he was smoking from the combination of sharp stinging sensation and a ticklish sensation. Always had this on every night. S could always feel the smoke in his mouth. There was never any time even for a single puff when S doubted that he was smoking. *It would not be possible for any one to persuade S that he was not smoking any of the time.*

(*Signed*) E. H.

With a suitable control dose, it is now possible to secure data which will enable us to interpret with confidence the pulse curve which previously baffled us. These supplementary data are represented by the broken line in Fig. 2. They were obtained from the same nine subjects as before, only this time they smoked nothing but warm air. Since they fully believed they were smoking tobacco,

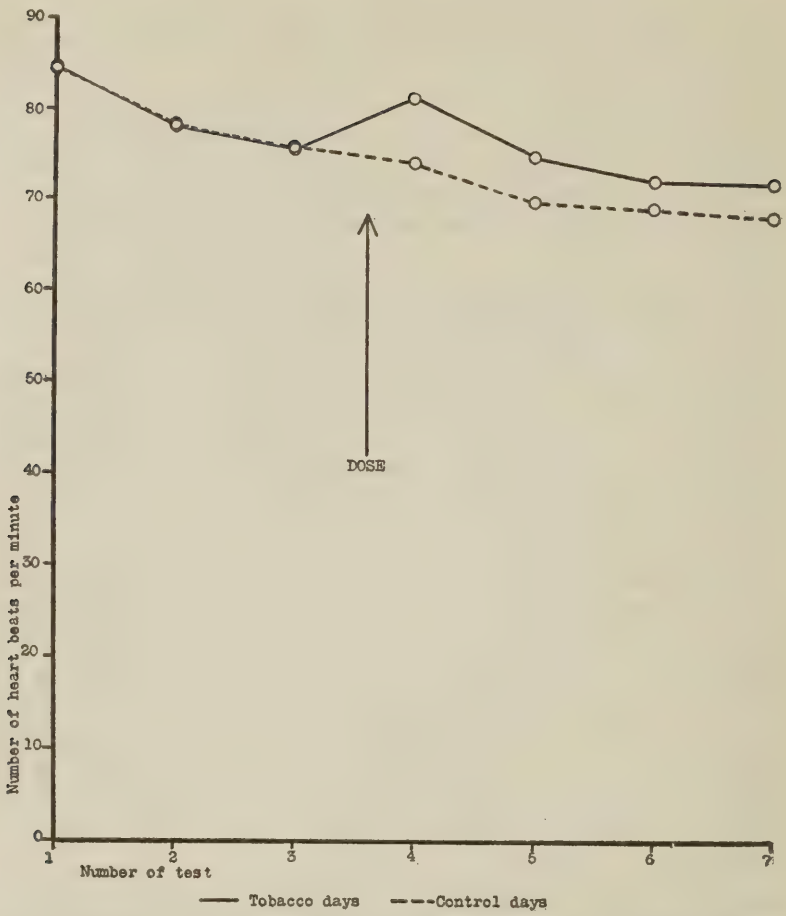

FIG. 2. The average heart rate of a group of habitual smokers on tobacco days and control days. The amount of separation of the curves after smoking indicates the tobacco effect.

suggestion, interest, excitement, personal bias for or against tobacco, states of tension or relaxation, processes of digestion, and any other obscure diurnal rhythms, are all constant. Previous to the dose the curves are seen to follow an identical course. Had no dose been taken we may assume that they would have continued to do so. After the dose they diverge. We can now say with approximate certainty that the smoking caused an increase in the

average pulse rate of these subjects, of a little over seven beats per minute. Moreover, instead of the stimulation disappearing at the end of 35 minutes as might have been supposed from Fig. 1, we find that nearly 70% of it still remains. And at the end of 1¾ hours, where a reversal of the influence seemed certain from Fig. 1, we find as a matter of fact that the stimulation still retains over 40% of its original intensity!

Similar curves illustrating the same principle but based upon a variety of other functions appear in Figures 11, 14, 15, 16, and 17.

The decision as to the number and the type of mental and neuro-muscular processes to be investigated, present certain difficulties. A drug may affect different functions quite differently. For this reason as well as from the point of view of the number of comparisons possible the more functions investigated the better. On the other hand, in tracing the course of a changing process such as the waning effects of a drug, it is desirable to locate as many points on the curves as possible in the allotted time, lest we miss some important transitory phase of the action. This is particularly true of the period immediately following the taking of the drug. But obviously the first test of a series is the only one that strictly tests the *immediate* effects of a drug, and the last test of a long series may even miss the effect entirely. From this second point of view, then, the *shorter* the series the better. These two conflicting points of view can be reconciled in part by a series of tests fairly large in number but capable of being given in a fairly short period of time. This means that the individual tests should be very brief and that no very lengthy test can be used at all. A list of twelve mental and neuro-muscular functions was finally adopted. Fortunately it was found possible so to devise the tests that in several cases two fairly distinct functions could be measured simultaneously. Partly owing to this, it was possible without haste, to give the entire series in 30 minutes.

The functions finally selected for investigation are listed below in the order of the increasing complexity of the neurol processes involved, and indication is given of the method used in measuring each:

1. Heart rate, measured by counting the radial pulse.

2. Tremor of the hand and arm, measured by Whipple's steadiness test.

3. Rate of voluntary movement, measured by the speed of tapping with a telegraph key.

4. Muscular fatigue, measured by the decrease in speed which results from continuous tapping.

5. Rate of discriminatory eye-hand reactions, measured by the speed of cancelling A's.

6. Accuracy of discriminatory eye-hand reactions, measured by the number of errors in cancelling A's.

7. Rate of eye-voice reactions which are based on old established associative bonds, measured by reading reaction-time.

8. Rate of eye-voice reactions which are based on recently formed associative bonds, measured by learning reaction-time.

9. Rate of continuous associative thought, measured by the speed of continuous mental addition.

10. Accuracy of continuous associative thought, measured by the accuracy of continuous mental addition.

11. Facility in the formation of short-lived associative bonds, measured by the auditory memory span for digits.

12. Rate of learning (formation of relatively permanent associative bonds), measured by the speed of memorizing non-sense material.

The order of the tests as administered to the subjects was determined after a preliminary series of experiments with four subjects, the results of which were discarded. The sequence finally chosen was the one which seemed to offer the most favorable opportunity for the various tests to yield reliable measures. It was as follows:

1. Pulse
2. Adding
3. Memory span
4. Steadiness
5. A-test
6. Reading reaction-time.
7. Memorizing
8. Tapping

Since neither pulse, adding nor memory span required the use of the eyes, these tests were placed first in the series to avoid any evil effects from the dark adaptation of the eyes following the removal of the blindfold after smoking. Steadiness was placed some distance from tapping to avoid increase of tremor likely to arise from the latter activity. Tapping was placed last so that no test whatever could follow it immediately. The reason that eight tests appear in the above list rather than twelve is that four of the tests give a simultaneous measure of two functions each.

The typical routine of a smoker subject's day may now be summarized. He went about his daily tasks as usual, carefully avoiding any unusual exercise or exertion and any alcoholic drinks or unusual foods. His smoking habits were not disturbed except that he agreed not to smoke during the three hours immediately preceding the experiment. Otherwise his smoking and, so far as possible, all the other activities of his life were to be kept as constant from day to day as possible. He finished his evening meal at about 6:25 and reported at the laboratory at 6:50 p.m.:

6:50 Pulse taken after which subject sat quietly for about 15 minutes.

7:05 Complete series of tests given as listed on p. 36, requiring 30 minutes. *This is the normal of the day.*

7:35 Pulse taken after which eight minutes were consumed in preparation for the smoking.

7:45 Began either smoking or taking the control dose, which lasted 25 minutes.

8:10 Experimenter puts away tobacco.

8:12 Complete series of tests repeated.

8:42 Subject rested for 5 minutes.

8:47 Complete series of tests repeated.

9:17 Subject rested for 5 minutes.

9:22 Complete series of tests repeated.

9:52 Pulse taken.

9:55 Subject excused.

The results of the first day of experimentation with each subject were always discarded as a practice or shock-absorber series,

though the subjects naturally were not informed of this.[13] There remained the results of 17 days which were available for statistical treatment. Of these, 9 were smoking days and 8 were control days. The sequence of the two types of days was a somewhat complex alternation designed both to neutralize any constant tendency to error due to practice effects and to avoid arousing the suspicions of the subject that any kind of alternation whatever was being used. The sequence employed in nearly all cases was as follows:

1. Smoke (thrown out)
2. Smoke
3. Control
4. Smoke
5. Control
6. Control
7. Smoke
8. Control
9. Smoke
10. Smoke
11. Control
12. Smoke
13. Control
14. Control
15. Smoke
16. Smoke
17. Control
18. Smoke

The above order was varied somewhat in a few cases where the subject was unable to complete the entire series of 18 days. The braces indicate practice-neutralizing groups based on a principle of symmetry, though the first group is not quite perfect. It will be shown in another connection, however, that practice errors were probably completely neutralized by another feature of the technique.

The experimental results must also be guarded against tenden-

[13] With two or three of the early subjects the second day was also thrown out but this was later found to be unnecessary.

cies to end spurt and other characteristic disturbances of the last day or two of experimentation resulting from the excitement of the subject over the fact that he has reached the end of a long and arduous experiment. These disturbances have been emphasized by Rivers.[14] They were easily avoided in the present investigation by engaging the subjects for 20 days and then excusing them at the conclusion of the work on the eighteenth day, two days before they had expected to finish.

The basic principle underlying the method of determining the effect of the tobacco on mental and motor efficiency, has been suggested above in a general way (pp. 26 and 34) by the discussion of the pulse rate in connection with the use of the control dose. The results on the control or non-drug days establish a standard or normal performance. If the results of the drug days follow, on the average, the same course as the standard performance, then we must assume that the drug has no effect whatever. If, on the other hand, the performance on the drug days deviates on the average from the standard performance more than chance experimental errors would ordinarily produce, we must assume that this deviation is caused by the tobacco. This is the fundamental principal upon which modern drug experimentation is based.

The principle of a standard performance was reinforced by a second principle, that of the normal test of the day. It has already been pointed out (p. 37) that both on the tobacco and on the control days, the tests were given once each day previous to the dose and three times after it. The test previous to the dose in each case is called the "normal of the day."[15] It is obvious that people are more vigorous and efficient on some days than on others. Practice effects in particular often cause the score on later days to be definitely higher than those of earlier days. If these practice effects were unequally distributed among the tobacco and the control days, they might easily produce an appearance of a drug effect where there is none at all[16] or indeed mask an effect which really exists. It is accordingly necessary to have a normal performance at the

[14] See page 24 above.

[15] Dodge and Benedict, Psychological Effects of Alcohol, p. 28.

[16] See Berry's results on errors in addition, Appendix F.

beginning of each experimental day to indicate the general level for that day. Once this is known, the results of the test following the dose can be expressed in terms which will be independent of this disturbing factor. The customary way of doing this is to tabulate the results of all the tests following the dose in terms of this normal of the day. Thus, immediately after the dose, a subject will be recorded as so much more (+) or less (—) efficient than before. The drug effect is then determined by comparing the average gain or loss in efficiency after the tobacco dose with that after the control dose. For example, if a given subject immediately after the control dose should average more efficient by 5 points, and after the tobacco dose, less efficient by —4 points, it is clear that the subject is less efficient by —9 points after smoking than he would have been had he not smoked, and irrespective of the accidental levels of efficiency originally characteristic of the two groups of days.[17]

The details of the method of determining the effects of smoking on mental efficiency which will be used uniformly throughout the present monograph, are illustrated in Table II. This shows the results on the adding test of subject No. 7 a non-smoker. It should first be noted that the table consists of three horizontal sections which are divided vertically into eight columns. The horizontal sections are devoted respectively to the results on the control days, the results on the tobacco days, and (at the bottom) the final net effect of the tobacco. In the first four of the columns (1, 2, 3, and 4) are recorded respectively the number of correct additions per-

[17] The above discussion neglects to consider the effects of practice from one test to the next on a single experimental day. It is assumed that the gain from this source will be equal for both the tobacco and the control days. This assumption is slightly complicated by the fact that practice curves are not straight but have a negative acceleration. The method of frequent alternation of smoke and control days was intended largely to eliminate this factor, as on any short segment of the practice curve it is practically straight. Any inequality still remaining will be equalized by the special practice-equalizing grouping of days of the type A. B, B′, A′ (p. 38). If A is slightly larger than B or B′, then A′ will be correspondingly smaller than B or B′ and the average of the two A's will be approximately that of the B's. As an added precaution, one of the groups is arranged in the order B A A′ B′. Hollingworth, in his work on caffeine, sought to eliminate the disturbing effects of practice by a preliminary period of training. This really eliminated only the first part of the curve.

formed during the four tests of each experimental days. In the next three columns (5, 6, and 7) are shown with appropriate signs, the gain or loss in efficiency over the normal of the day, of each of the three tests following the dose. The last column (8) gives the average net gain or loss in efficiency on the three post-dosage tests recorded in columns 5, 6, and 7. A plus sign always means a gain in efficiency or a stimulation and a minus sign a loss in efficiency or a depression.

To illustrate: On March 17, a control day, the subject performed 166 correct additions before the dose (the normal of the day) and 175 immediately after the dose. This is a gain of (+) 9 points in adding efficiency and as such is recorded in column 5. On test III (40 minutes after the dose) he made 186 correct additions which is (+) 20 points more efficient than the normal of the day (166), so 20 appears in column 6. On test IV, an hour and a quarter after the dose, he performed 172 correct additions which is a gain in efficiency over the normal of the day of 6 points. This is recorded in column 7. The three post-dosage tests thus scored for efficiency show an average gain of (+) 11.6 points. This is recorded in column 8.

The average gain or loss in efficiency for a given post-dosage test on a given set of experimental days, is found by adding algebraically the efficiency scores in appropriate column and averaging. These averages are shown in special type. Thus the first post-dosage tests on the control days (column 5) average a gain in efficiency of 2.4 points, whereas the corresponding test for the tobacco days averages a loss of —5.5 points. The subject therefore was less efficient in addition after smoking than after the control dose, by —7.9 points. This, then, within the limits of experimental error, is the final net effects of the tobacco, and as such is recorded in the appropriate column (5) of the third and lowest section of the table. The percent of gain or loss in efficiency is computed on the basis of the average of the means of the normal tests of the day of the control days and the tobacco days respectively. In the record under consideration, one mean is 222.5 and the other 226.9, which yield an average of 224.7. By simple division, —7.9 is found

to a 3.5% loss in efficiency and as such is recorded at the bottom of column 5.

The nature and the size of the difference having been found, it is next necessary to determine whether this difference is probably

TABLE II

Adding, subject No. 7, non-smoker. Score, number of correct additions performed in five minutes. Plus means a gain in efficiency as result of smoking, minus means a loss.

	Original scores				Difference between normal of day and subsequent tests			
	(1) Test	(2) Test	(3) Test	(4) Test	(5) Test	(6) Test	(7) Test	(8) Average
Control days: (Normal)	I	II	III	IV	II	III	IV	difference
Mar. 17	166	175	186	172	+ 9	+20	+ 6	+11.6
" 19	193	194	200	190	+ 1	+ 7	— 3	+ 1.6
" 20	198	183	193	216	—15	— 5	+18	— .6
" 22	209	218	198	207	+ 9	—11	— 2	— 1.3
" 25	242	254	273	257	+12	+31	+15	+19.3
" 26	240	243	266	256	+ 3	+26	+16	+15.0
" 28	269	268	281	282	— 1	+12	+13	+ 8.0
" 31	263	264	274	286	+ 1	+15	+23	+13.0
Total	1780	1799	1875	1866	+19	+95	+86	+66.6
Average	222.5	224.9	234.4	233.2	**+ 2.4**	**+11.9**	**+10.7**	**+ 8.3**
M. V.					5.87	11.15	7.82	6.4
P. E.$_M$					1.75	3.32	2.33	1.91
Tobacco days:								
Mar. 16	143	154	150	147	+11	+ 7	+ 4	+ 7.3
" 18	183	175	170	189	— 8	—13	+ 6	— 5.0
" 21	200	197	185	187	— 3	—15	—13	—10.3
" 23	212	210	221	235	— 2	+ 9	+23	+10.0
" 24	238	247	235	243	+ 9	— 3	+ 5	+ 3.6
" 27	258	247	256	265	—11	— 2	+ 7	— 2.0
" 29	260	255	269	264	— 5	+ 9	+ 4	+ 2.6
" 30	282	282	262	252	—35	—20	—30	—28.3
Apr. 1	266	260	270	248	— 6	+ 4	—18	— 6.6
Total	2042	1922	2018	2030	—50	—24	—12	—28.7
Average	226.9	221.3	224.2	223.5	**— 5.5**	**— 2.6**	**+ 1.3**	**+ 3.2**
M. V.					8.39	8.95	12.65	8.32
P. E.$_M$					2.36	2.52	3.56	2.34
Effect of Tobacco:								
Difference					**— 7.90**	**—14.50**	**—12.00**	**—11.50**
P. E.$_D$					2.935	4.17	4.25	3.02
Ratio					2.69	3.47	2.82	3.80
Reliability					.965	.990	.971	.995
Per cent gain or loss					**— 3.5%**	**— 6.4%**	**— 5.3%**	**— 5.07%**

caused by the tobacco or is the result of accidental factors. The issue depends upon the size of the difference found in relation to its probable error (P. $E._D$).[18] The general characterictics of this dependence will become evident upon a little consideration. If with a small number of measures upon a given subject, we should find that the tobacco days averaged the same as the control days, it would not necessarily mean that the tobacco had no effect whatever on adding efficiency. With an indefinitely large increase in the number of measures, the two averages might turn out to be perceptibly different. Now it is obvious that in advance of trial, such a change is as likely to be in the direction of a loss in efficiency as of a gain. That is, out of 1000 chances there are 500 that the true average is in reality a loss of greater or less amount, and 500 that is a gain of greater or less amount. But, in case the averages from a limited number of measures yield a difference indicating a loss in efficiency say, and as great as the P. $E._D$, then the chances that an infinite increase of the measure would reveal a loss as the true average, is increased from 500 chances to 750 in 1000. The chances of its revealing a gain in efficiency is correspondingly decreased to 250. Or, if the difference found is twice as large as the P. $E._D$ and in the direction of a loss, then the chances that the true average from an infinite number of measures will show a loss is increased to 911 with only 89 chances that it will show a gain. Thus the larger the difference found in proportion to the P. $E._D$, the greater the probability that the true difference is at least in the same direction as found, and the less the chance that it is in the opposite direction.

[18] For the benefit of the non-technical reader the process of arriving at the P. $E._D$ may briefly be indicated. The mean variation (M. V.) of each of the two sets of scores (as in column 5) is determined by first finding the algebraic difference between each item in a given set of scores and their average. The average of these differences is called the M. V. The probable error of the mean or average of a given set of scores (P. $E._M$) is next computed by the formula $\text{P. E.}_M = \frac{.8453 \text{ M. V.}}{\sqrt{N}}$ where N is the number of scores from which the average was computed. Lastly, if we call the probable error of the mean of the control days, P. $E._{M_1}$ and that of the tobacco days P. $E._{M_2}$, the probable error of the difference between the two averages is computed by the formula:

$$\text{P. E.}_D = \sqrt{\text{P. E.}^2_{M_1} + \text{P. E.}^2_{M_2}}$$

The following table summarizes these various relations in a systematic manner. This shows that with a difference as large as

TABLE III

Differences between averages (assumed to show a loss if greater than zero)	Number of chances in 1000 that the true average will show		The chance that the difference found will be reversed
	a loss	a gain	
Of Zero	500	500	1 in 2
As large as the P. $E._D$	750	250	1 in 4
Twice the P. $E._D$	911	89	1 in 10
Three times the P. $E._D$	979	21	1 in 47
Four times the P. $E._D$	997	3	1 in 285
Five times the P. $E._D$	999.6	.4	1 in 2632
Six times the P. $E._D$	999.97	.03	1 in 33,333

6 time the P. $E._D$, complete certainty is not obtained. Theoretically even here, there is one chance in some 33,333 that the true difference would be opposite to that found. Such a remote probability is of course quite negligible as is also 1 case in 2,632. On the other hand one chance of a reversal in 2 or 4 is so great as to be altogether beneath serious consideration. The lowest reliability that is ever used to base action upon in practice is twice the P. $E._D$, which yields 1 chance of a reversal in about 10. A difference three times the P. $E._D$, which yields only 1 reversal in about 47 cases, is considered practical certainty. The smallest reliability to be considered seriously in the present report unless supported by other evidence is 950, i.e., one yielding 1 chance of error in 20.

It is customary to express the reliabilities of differences between averages as decimals of perfect reliability which is 1. Thus for a

zero difference the reliability will be .500, for once the P. $E._D$ it will be .750, for twice the P. $E._D$ it will be .911 and so on down the second column of Table III except that a decimal point is placed before the numbers as listed there.

Applying the foregoing considerations to the results given in Table II, we find that the difference of —7.9 already noticed, has a probable error of 2.935 which is recorded beneath it in column 5. By division, the difference is found to be 2.69 times as large as its probable error. This is also recorded. By referring to a table giving values of the probability integral for probable errors[19] we find that 2.69 corresponds to 965 chances in 1000 that the true average would show a loss in efficiency. Assuming that the method of the experiment is sound this means that there is only one chance in about 28 that tobacco did not cause a loss in efficiency in this subject. This is easily within the conventional limit of reliability adopted above as satisfactory. The reliabilites of the differences found on the second and third post-dosage tests are .990 and .971 respectively while that of the averaged data in column 8 is 995. This latter figure means that there is only one chance in about 200 that the smoking did not have a detrimental effect on the subject's adding efficiency throughout the period investigated.

But the issue can not be settled by the results from a single subject, no matter of how high a reliability. In drug action individual peculiarities are common. Our present interest is not primarily with idiosyncrasies but with characteristic reactions shared by people in general. The effect of tobacco for us, then must be decided primarily by the nature of the average effect obtained from a group of subjects representative of the general population of non-smokers and habitual smokers. And the reliability that in the end will be decisive will be the reliability of this average. Its determination will briefly be indicated in the next chapter.

[19] Thorndike, E. L., Mental and Social Measurements, p. 200. It will be noted that 500 has to be added to each entry in this table, since 500 chances are in favor of a loss, say, with a zero difference between the averages.

CHAPTER III

The Effect of Smoking on the Heart Rate

Pulse rate was introduced into the present experiment after the first six non-smokers had been tested. The function in question is obviously physiological and only remotely psychological, though involving important neuro-muscular mechanisms. Preliminary observations on some of the early subjects, however, as well as the results reported by other investigators,[1] had indicated that the heart rate is a rather sensitive and reliable index of the action of tobacco smoking on the human organism. It was accordingly introduced into the series of tests for purposes of comparison and also as a kind of control for such mental processes as should fail to show any reliable effects at all. The heart rate was determined by the simple counting of the radial pulse for one minute, the subject sitting. The subject's wrist was held for about 20 seconds before counting was begun in order that the slight excitement often arasing at such times, should have an opportunity to subside. A typical set of pulse data is shown in Table IV. They are the results from subject No. 15, habitual smoker.[2] The pulse was counted seven times on each experimental day—three times before the dose and four times after. The detailed circumstances have been described above (p. 25) in connection with the account of the control dose. The average of the second and third counts was taken as the normal of the day and is recorded in the table as "Test 1." The various computations have been made as outlined at the end of Chapter II. The table shows that with this subject all

[1] See above pp. 6-7.

[2] Similar tables of the results from this subject will be used throughout the remainder of the present monograph for illustrative purposes. In this way it is hoped that the reader may secure a tolerably complete picture of a typical set of experimental results. A smoker was chosen for this purpose because the problem of the effects of smoking on this group of subjects is more acute since they represent the part of the population which does the smoking. This particular subject was chosen because his results happen to agree with the average from his group better than the others. In this sense the hasty reader may consider his record as typical of the entire group.

TABLE IV

Pulse, subject No. 15, habitual smoker. Score, number of beats counted in one minute.

	Original Scores					Difference between normal of day and subsequent tests				
Control days:	Test I (Normal)	Test II	Test III	Test IV	Test V	Test II	Test III	Test IV	Test V	Average Difference
Nov. 8	80.5	73	75	71	71.5	— 7.5	— 5.5	— 9.5	— 9	— 7.87
" 10	92	84	77	77	77	— 8.0	— 15.0	— 15.0	— 15	— 13.25
" 11	76	70	70	72	66	— 6.0	— 6.0	— 4.0	— 10	— 6.50
" 13	103	80	78	71	70	— 23.0	— 25.0	— 32.0	— 33	— 28.25
" 16	86	74	78	71	67	— 12.0	— 8.0	— 15.0	— 19	— 13.50
" 18	94	82	79	79	76	— 12.0	— 15.0	— 15.0	— 18	— 15.00
" 19	100.5	83	76	82	70	— 17.5	— 24.5	— 18.5	— 30.5	— 22.75
" 22	97	72	77	64	67	— 25.0	— 20.0	— 33.0	— 30	— 27.00
Total	729.0	618	610	587	564.5	—111.0	—119.0	—142.0	—164.5	—134.12
Average	91.12	77.25	76.25	73.37	70.56	**— 13.87**	**— 14.87**	**— 17.75**	**— 20.56**	**— 16.76**
M. V.						5.96	6.28	7.56	7.95	6.92
P. E_M						1.78	1.88	2.26	2.38	2.07
Tobacco days:										
Nov. 7	74	79	82	76	93	+ 5	+ 8	+ 2	+ 19	+ 8.50
" 9	88	76	83	84	76	— 12	— 5	— 4	— 12	— 8.25
" 12	88	76	94	76	69	— 12	+ 6	— 12	— 19	— 9.25
" 14	84.5	72	84	75	70	— 12.5	— 0.5	— 9.5	— 14.5	— 9.25
" 15	97	73	90	82	74	— 24	— 7	— 15	— 23	— 17.25
" 17	86	74	82	82	79	— 12	— 4	— 4	— 7	— 6.75
" 20	88.5	75	84	83	82	— 13.5	— 4.5	— 5.5	— 6.5	— 7.50
" 21	98	75	80	70	69	— 23	— 18	— 28	— 29	— 24.50
" 23	85	67	80	73	72	— 18	— 5	— 12	— 13	— 12.00
Total	789.0	667	759	701	684	—122.0	— 30.0	— 88.0	—105.0	— 86.25
Average	87.66	74.11	84.33	77.89	76	**— 13.55**	**— 3.33**	**— 9.78**	**— 11.66**	**— 9.58**
M. V.						5.41	5.22	6.20	9.0	5.56
P. E_M						1.52	1.47	1.75	2.54	1.57
Effect of Tobacco										
Difference						+ **.32**	+ **11.54**	+ **7.97**	+ **8.90**	+ **7.18**
P. E_D						2.34	2.39	2.86	3.48	2.60
Ratio						.137	4.838	2.786	2.557	2.761
Reliability						.54	.999	.97	.957	.968
Per cent gain or loss						+ **.35**	+ **12.90**	+ **8.91**	+ **9.95**	+ **8.03**

the postdosage tests yield a stimulation and all but one (including the average) have a satisfactory statistical reliability.

As pointed out at the end of the last chapter, the results from one subject, no matter of how high a reliability, can hardly be taken as conclusive evidence of the nature and extent of the influence of a drug on a population in general, because people may differ in their reactions. We must accordingly test a group of individuals chosen at random from the population. This presents a new statistical problem. In Tables II and IV above, the reliability of the final results was attenuated by the varying of a subject from himself on different days. This, in a measure, was compensated for by the large number of experimental days. We now find the reliability of the average results from a group of subjects suffering from the variability of one subject from another in the nature and extent of his response to the drug. In this case compensation must lie in the large number of subjects tested.

The final results of the present investigation as to heart rate are summarized in Table V and VI. It will be observed that these tables are constructed by merely assembling the essential data from the lowest horizontal section of the tables of the individual subjects, such as Table II. This will be clear to the reader if he will note the results of subject 15 as they appear in the third section of Table IV and as they reappear in Table VI. Thus, under each post-dosage period in Table VI, there appear both the absolute difference in heart rate due to the tobacco and the percentage effect, together with the probable error and the reliability of the former. The two columns representing the effect of the drug are each averaged with due consideration of the sign of the various entries, after which the P. $E._M$ and reliability of type A is computed for each. This reliability is obtained by dividing the average effect by its probable error (P. $E._M$) and then looking up the reliability in a table as indicated on p. 45. The third reliability (Type B) has a somewhat different meaning. Theoretically, it corresponds approximately to what would have been the reliability if there had been no variability among the various subjects in their reactions to the drug, but only a variability of each subject from his own central tendency from day to day.[3] This latter variability is expressed in the average of the column of P. E.'s, which, for the

Table V

Effect of Tobacco on Heart Rate, Non-smokers

Score, number of pulse beats counted in one minute. Plus means a stimulation as result of smoking, minus means a depression.

Subject Number	Effect, first post-dosage test (after 2 min.)				Effect, second post-dosage test (after 37 min.)				Effect, third post-dosage test (after 1 hr. 12 min.)				Effect, fourth post-dosage test (after 1 hr. 43 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
[1]																
7	+ 4.27	1.25	.989	+ 5.35	+ .50	1.22	.608	+ .60	+4.00	1.47	.966	+5.00	+2.60	1.36	.901	+3.20
8	+ 7.33	1.05	1.000	+11.04	+3.23	.722	.999	+4.80	+1.75	1.07	.864	+2.60	+1.31	1.10	.789	+1.97
9	+15.20	1.65	1.000	+22.88	+2.79	1.415	.908	+4.20	+ .11	1.18	.525	+ .16	+ .36	1.54	.561	+ .54
Average	+ **8.93**	1.32		**+13.09**	**+2.17**	1.12		**+3.20**	**+1.95**	1.24		**+2.59**	**+1.42**	1.33		**+1.90**
M. V.	4.18			6.53	1.12			1.73	1.36			1.62	.783			.91
P. E.$_M$ (A)	2.04			3.19	.547			.844	.664			.789	.382			.444
Reliability (A)	**1.00**			.997	**.996**			.995	**.975**			.986	**.993**			.998
P. E.$_M$ (B)	.762				.647				.716				.768			
Reliability (B)	1.000				.988				.966				.894			

[1] The pulse was not taken on the first six non-smokers.

TABLE VI

EFFECT OF TOBACCO ON HEART RATE, HABITUAL SMOKERS

Score, number of pulse beats counted in one minute. Plus means a stimulation as result of smoking, minus means a depression.

Subject Number	Effect, first post-dosage test (after 2 min.)				Effect, second post-dosage test (after 37 min.)				Effect, third post-dosage test (after 1 hr. 12 min.)				Effect, fourth post-dosage test (after 1 hr. 43 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	+ .90	1.46	.661	+ 1.20	.00	1.59	.500	.00	—1.80	1.82	.747	— 2.40	(1)			
11	+ 4.10	2.26	.890	+ 4.90	+ 2.40	2.35	.764	+ 3.	+ .80	1.58	.632	+ .96	+6.00	1.22	.999	+7.20
12	+ 6.50	1.48	.999	+ 6.90	+ 3.90	1.71	.938	+ 4.10	+ .60	1.94	.583	+ .64	+1.00	1.65	.660	+1.07
13	+ 4.49	.85	1.000	+ 6.53	+ 4.99	1.17	.995	+ 7.26	+3.33	1.20	.970	+ 4.84	+2.74	1.30	.922	+3.99
15	+ .32	2.34	.540	+ .35	+11.54	2.39	.999	+12.90	+7.97	2.86	.970	+ 8.91	+8.90	3.48	.957	+9.95
16	+14.25	1.87	1.000	+16.82	+10.97	2.59	.999	+12.95	+9.76	2.10	.999	+11.52	+7.25	2.20	.986	+8.56
17	+10.56	1.31	1.000	+14.95	+ 9.05	1.21	1.000	+12.81	+6.05	1.21	.999	+ 8.56	+2.56	2.03	.802	+3.62
18	+ 4.07	1.58	.959	+ 5.09	+ 3.37	1.28	.962	+ 4.22	+3.49	1.59	.930	+ 4.37	+2.65	1.40	.899	+3.31
19	+12.63	1.42	1.000	+18.37	+ 5.62	2.23	.955	+ 8.17	+2.15	1.68	.836	+ 3.12	+6.37	1.28	.999	+9.26
Average	**+ 6.42**	1.62		**+ 8.35**	**+ 5.76**	1.83		**+ 7.27**	**+3.59**	1.78		**+ 4.50**	**+4.68**	1.82		**+5.87**
M. V.	4.05			5.58	3.16			3.95	2.89			3.52	2.45			2.87
$P.E._M$ (A)	1.14			1.57	.89			1.11	.81			.99	.69			.86
Reliability (A)	**1.00**			1.00	**1.00**			1.00	**.999**			.999	**1.00**			1.00
$P.E._M$ (B)	.54				.61				.59				.64			
Reliability (B)	1.00				1.00				1.000				1.00			

[1] The pulse of this subject was not taken at the conclusion of the day's testing as with the other subjects.

first post-dosage test, is 1.62. This average is next divided by the square root of the number of entries (9) which is 3, on the principle that the probable error of an average (e.g. 6.42) is inversely proportional to the square root of the number of measures upon which it is based. This division yields .54 for the P. $E._M$ of type B. From this a second reliability (Type B) is computed for the average (6.42) in the usual way. The average of the absolute effects of the tobacco together with its reliability of type A are considered of most significance and accordingly are printed in more conspicuous type. The two remaining reliabilities are valuable chiefly as supplementary evidence.

A glance at the body of Table VI shows that the habitual smokers, almost without exception, received a stimulation from the smoking. While the non-smokers are too few in number to base extensive generalizations upon, they show the same general tendency. If there is any difference between the two groups it is that the non-smokers have a somewhat greater immediate stimulation than the habitual smokers but recover from it somewhat more quickly. Two minutes after smoking, the habitual smokers show an average stimulation of 6.4 beats per minute. This falls to 5.76 beats stimulation 37 minutes after smoking, to 3.59 beats 1 hour and 12 minutes after, but rather unexpectedly shows a slight *increase* in stimulation after 1 hour and 43 minutes.

This apparent increase at the end of the experimental day is due in part to the fact that subject No. 10 had no entry on the last post-dosage test. This fact does not account for the gain, though, because a tendency in the same direction is apparent in Fig. 2 where the missing data for this subject were supplied by interpolation. The facts are brought out still more clearly by Fig. 3

[3] Another way of saying the same thing would be to say that the reliability of type A gives the probability of getting the same type of result if the experiment were repeated with new subjects chosen at random, whereas that of type (B) gives the probability if it were repeated with the *same* subjects. If this assumption were strictly true, the P. $E._M$ of type B ought never to exceed the P. $E._M$ of type A except as result of chance sampling, and should usually be less. This, while true in the tables under consideration, is by no means always the case. The rather general equality of the two types of P. E. would seem to indicate that the individual differences in the response to tobacco are not very great.

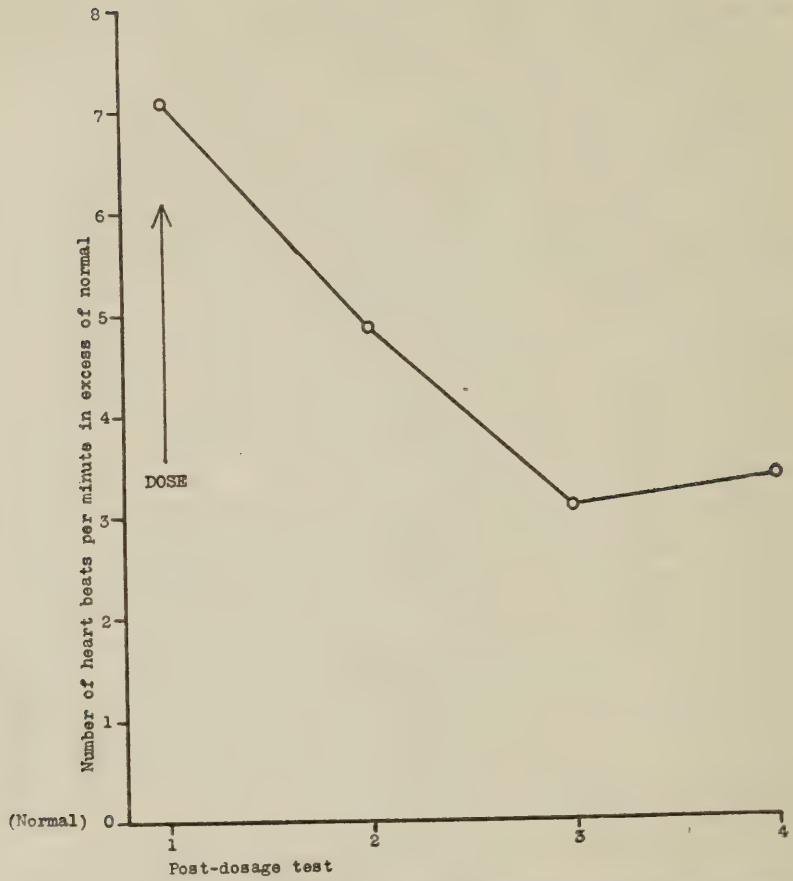

FIG. 3. The return of the heart rate to normal after smoking, habitual smokers.

which shows the amounts of stimulation on each of the four post-dosage tests.[4] Here we can see the rate falling uniformly towards the normal throughout the post-dosage period except at the end of the experimental day. Here, instead of continuing to fall as one might naturally expect, we find an actual rise. This curve is based

[4] It should be pointed out that the data upon which the curve of Fig. 2 is plotted included *all* the experimental days, whereas that of Table VI included all but the first day of each subject just as with the other tests. For this reason there are minor differences between the curves and the table. Fig. 3 is plotted from the same data as Fig. 2.

upon averages from such a very large number of data that this interruption in the return to normal cannot be due to chance. The explanation seems to be that the group of subjects as a whole had a tendency to a mild excitement at the approach of the end of the somewhat arduous experimental day. Owing to the control methods used, it is quite clear, of course, that for such an effect to be produced, the causal factor must operate more strongly on the tobacco days than on the control days. Indeed it is in this that its chief significance probably lies.

It will be seen (Table VI) that the reliabilities of all the averages and of both types are extremely high, which indicates that there is no question but that smoking stimulates the heart rate. In most cases the reliabilities are 1.000 or perfect. As a matter of fact perfect reliabilities are never obtained from such data. The 1.000 was recorded in each case because the actual figures obtained by the computation were nearer to 1.000 than to .999.

Certain conclusions may be drawn from the above results:

1. Tobacco smoking causes a fairly uniform stimulation of the heart rate.

2. This stimulation, while disappearing fairly uniformly with the passage of time, is by no means gone an hour and 43 minutes after the termination of the smoking.

3. Habituation to the use of tobacco seems to have little or no tendency to establish a tolerance with respect to heart rate.

4. The heart rate appears to be more susceptible to the influence of interest and excitement after smoking.

The high degree of statistical reliability of the chief results summarized above, together with the fact that they agree in detail with the findings of both Payne and Dowling (see above p. 6 ff.) enable us to consider them as established.

CHAPTER IV

The Effect of Smoking on the Steadiness of the Hand

In the present chapter, we pass from the automatic activity of the heart to a consideration of the involuntary muscular tremor of the arm and hand. It is assumed that steadiness is a desirable trait and that the steadier the hand the more efficient the voluntary muscular control. A certain amount of tremor is, of course, normal. The question before us is: Does the smoking of a pipe of tobacco increase or decrease this amount?

The method used in measuring the amount of tremor in the present experiment was adapted from Whipple.[1] The apparatus consists essentially of a stylus and a white metal plate which is pierced with two rows of holes of progressively varying size (Plate 4). The subject was seated comfortably in a swivel chair with the plate placed on the edge of the table before his right hand. The stylus was held like a pencil. The subject was directed to get in readiness and at the signal "Go" to place the stylus in the right-hand hole of the upper row and hold it there so far as possible without touching the plate, until told to stop. The arm was held well away from the body with the elbow bent at an angle of about 110 degrees. The hole was 5.1 millimeters in diameter while the stylus was 3.1 millimeters in diameter. The time interval used was 1 minute and was measured by a stop-watch. The score was the number of contacts made by the stylus during the one-minute period.

The number of contacts made was automatically recorded by an electric counter which was placed in circuit with the plate, stylus and several batteries, in such a way that when the stylus touched the plate a current passed through the counter and was instantly registered. The hand of the counter was always placed on zero at the beginning of the test so that the score could be read off directly without computation at the end of the minute. Connected with the same electric circuit but shunted around the electric counter was

[1] Whipple, G. M. Mental and Physical Tests, Simpler Processes, p. 155 ff.

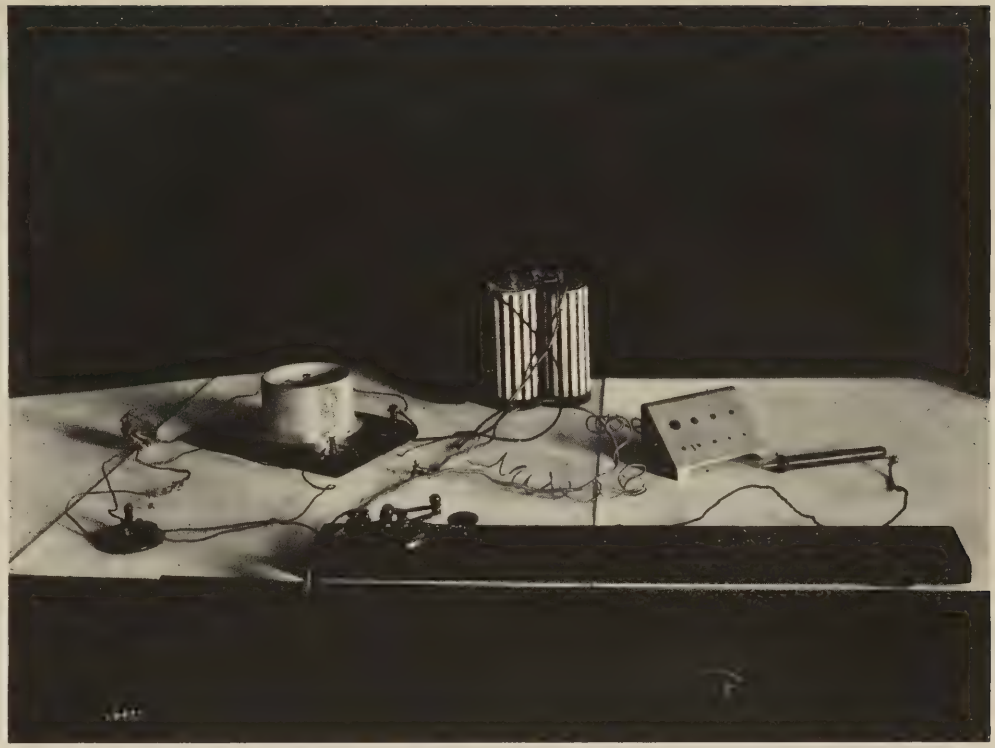

PLATE 4. Apparatus used in the tremor and tapping tests. When in use the electric counter, batteries, buzzer, and switch were all concealed from the subject's view by a screen.

an electric buzzer which sounded during each contact. The buzzer served to warn both subject and experimenter of any tendency to permanent contact. Both buzzer and counter, though on the same table, were placed behind a black screen partly to prevent distraction of the subject's attention but especially to prevent the subject from noting his score and thus setting up a possible vicious suggestion. For similar reasons the subjects were directed in their preliminary instructions, never to ask for their scores or indeed to think about them at all except to do their best on every test.[2]

The detailed results of a typical habitual smoker (subject No. 15) are shown in Table VII. The method of computing the effect of the tobacco is similar to that described above, pp. 39-45 and 48-51. On the second test of the day (first post-dosage test) this subject shows a distinct gain in efficiency on the control days but a very marked loss in efficiency on the tobacco days. The immediate net effect of the tobacco on this subject is an increase in tremor of slightly more than 21 contacts per minute, over a normal of about 12. This amounts to an increase of over 182%. On the fourth test, however, at the conclusion of the experimental period and an hour and 23 minutes after the conclusion of the smoking, this has practically disappeared. It may also be noted that the statistical reliability of the results of all but this one period are very satisfactory.

The final results of the investigation of the effects of smoking on steadiness are summarized in Tables VIII and IX for the non-smokers and the habitual smokers respectively. These tables are constructed and the various computations made exactly as in the corresponding tables given on pp. 49-50. An examination of these tables shows at once that the smoking has resulted, upon the whole, in a distinct increase in the tremor of both groups of subjects. This is particularly striking with the habitual smokers, where the increase in tremor on the first post-dosage test averages over 60%. About half of this increase has disappeared 48 minutes after the smoking, however, and only a trace is left 1 hour and 23 minutes after.

[2] These instructions were general and applied to all the tests alike.

A graphic comparison of the average course of the tremors on the tobacco and on the control days is shown in Figures 4 and 5. In Fig. 5 the marked divergence of the two curves after the dose, shows the great increase in tremor of the habitual smokers immediately after the dose, while the drawing together of the curves

TABLE VII

Tremor, subject No. 15, habitual smoker. Score, number of contacts stylus made in hole during one minute.

	Original scores				Difference between normal of day and subsequent tests			
Control days:	Test I (Normal)	Test II	Test III	Test IV	Test II	Test III	Test IV	Average Difference
Nov. 8	19	11	10	7	+ 8	+ 9	+12	+ 9.66
" 10	10	15	5	3	— 5	+ 5	+ 7	+ 2.33
" 11	16	6	8	9	+ 10	+ 8	+ 7	+ 8.33
" 13	12	12	3	6	0	+ 9	+ 6	+ 5.00
" 16	13	18	3	10	— 5	+ 10	+ 3	+ 2.66
" 18	5	4	4	8	+ 1	+ 1	— 3	— .33
" 19	6	2	5	0	+ 4	+ 1	+ 6	+ 3.66
" 22	3	1	4	9	+ 2	— 1	— 6	— 1.66
Total	84	69	42	52	+ 15	+ 42	+32	+ 29.66
Average	10.5	8.62	5.25	6.5	**+ 1.87**	**+ 5.25**	**+ 4.0**	**+ 3.707**
M. V.					4.13	3.75	4.5	2.97
P. E_M					1.23	1.12	1.34	.887
Tobacco days:								
Nov. 7	21	36	18	6	— 15	+ 3	+15	+ 1.00
" 9	6	20	23	12	— 14	— 17	— 6	— 12.33
" 12	19	62	35	19	— 43	— 16	0	— 19.66
" 14	25	53	28	39	— 28	— 3	—14	— 15.00
" 15	13	43	31	5	— 30	— 18	+ 8	— 13.33
" 17	12	36	8	4	— 24	+ 4	+ 8	— 4.00
" 20	5	10	12	2	— 5	— 7	+ 3	— 3.00
" 21	10	20	11	3	— 10	— 1	+ 7	— 1.33
" 23	6	13	24	2	— 7	— 18	+ 4	— 7.00
Total	117	293	190	92	—176	— 73	+25	— 74.66
Average	13	32.55	21.11	10.22	**— 19.55**	**— 8.11**	**— 2.77**	**— 8.295**
M. V.					10.39	8.12	6.30	6.03
P. $+_M$					2.93	2.29	1.77	1.70
Effect of Tobacco:								
Difference					**— 21.42**	**— 13.36**	**— 1.22**	**— 12.00**
P. E_D					3.18	2.55	2.22	1.92
Ratio					6.74	5.24	5.49	6.25
Reliability					.99997	.9998	.6447	.99997
Per cent gain or loss					**—182.29**	**—113.70**	**—10.38**	**—102.12**

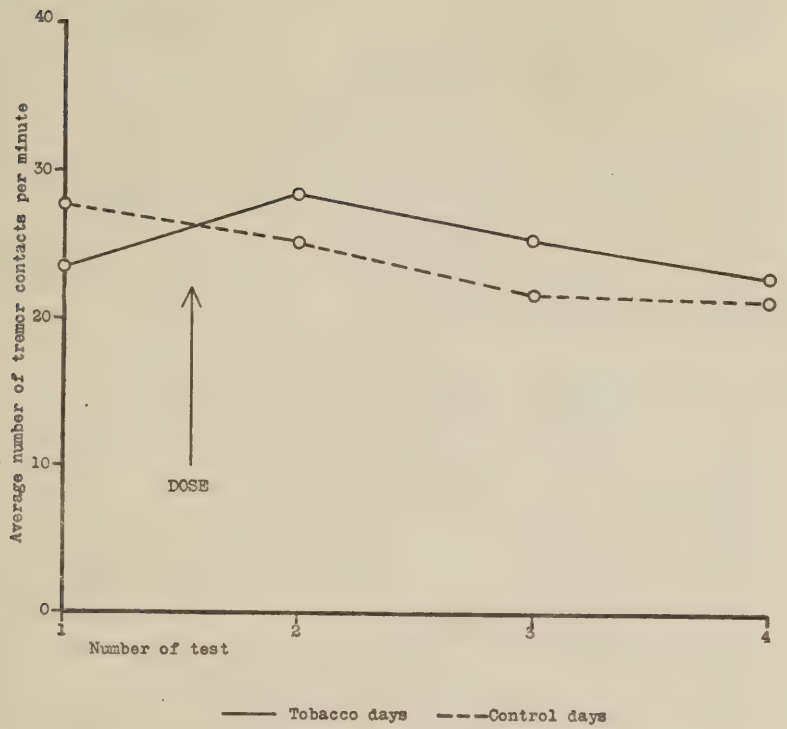

FIG. 4. The effect of smoking on tremor of the hand, non-smokers.

at the end of the period indicates the gradual recovery pointed out above. For some reason the average of the pre-dosage tests of the non-smokers on the tobacco days differs considerably from the corresponding average on the control days. This makes the detailed interpretation of the data from this particular set of subjects somewhat uncertain. From the data taken as a whole, however, a number of facts stand out quite clearly. They may briefly be summarized as follows:

1. The smoking of a pipe of tobacco produces a marked increase in the tremor of the arm and hand.

2. With the ordinary smoker, recovery is nearly complete an hour and 23 minutes after the termination of the smoking.

3. Habituation seems, if anything, to have increased the susceptibility of subjects to this particular action.

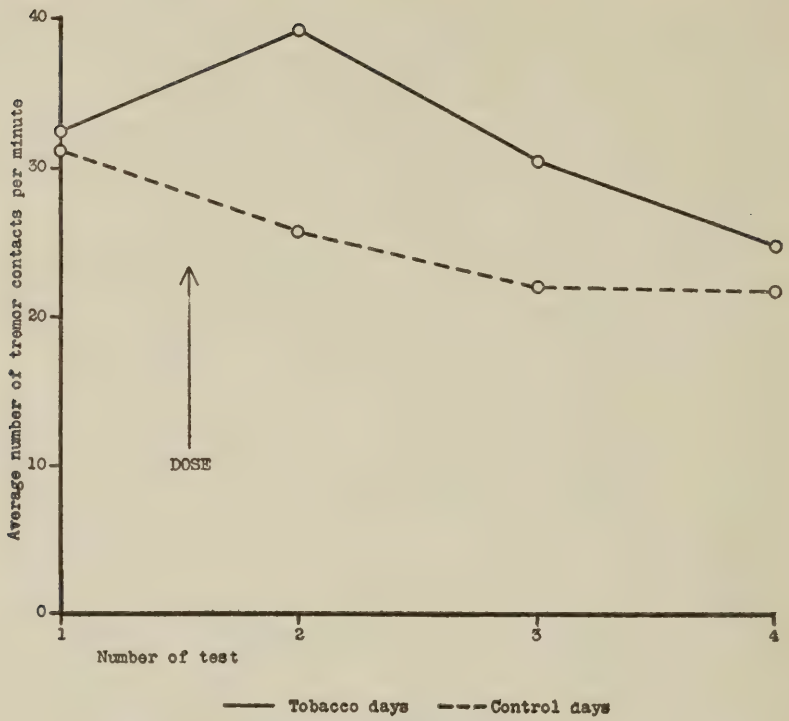

FIG. 5. The effect of smoking on tremor of the hand, habitual smokers.

The above results harmonize well with the findings of previous investigators, in so far as comparable data have been reported. Such as are available have been described in some detail above (p. 7). If anything, the present results show a smaller increase in tremor as a result of smoking than has usually been found. Froeberg, whose results are probably the best in this respect, found an increase of 120% with non-smokers. Unfortunately, he does not state how many minutes after the termination of the smoking this particular test was made, though there are certain indications that it was given immediately. If this be true, the divergence may be attributed, in part at least, to the fact that this test in the present series came some 13 minutes after the smoking. During this period there must have been considerable decrease in the tremor if we may judge by what took place afterward (see curve, Fig. 5.) At all events, there is perfect agreement that smoking causes a marked

TABLE VIII

EFFECT OF TOBACCO ON TREMOR, NON-SMOKERS

Score, number of tremor contacts of stylus in hole during one minute. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 13.5 min.)				Effect, second post-dosage test (after 48.5 min.)				Effect, third post-dosage test (After 1 hr. 23.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
[1]												
3	— 6.50	2.49	.960	— 21.70	— 8.51	2.65	.985	—28.40	—7.90	2.81	.971	—26.40
4	+ .40	4.12	.526	+ 1.60	— 5.60	4.44	.802	—23.50	—2.90	3.10	.735	—12.10
5	— 1.33	3.505	.600	— 3.26	— 9.90	4.17	.944	—24.26	—7.80	5.03	.852	—19.10
6	— 7.50	1.358	1.000	— 85.20	— 1.90	1.13	.871	—21.50	—2.00	1.50	.815	—22.70
7	—10.40	2.97	.990	— 48.10	— 7.15	2.97	.947	—33.10	—8.81	2.09	.998	—40.70
8	— 9.50	3.64	.961	— 25.70	— 7.70	3.14	.951	—20.80	—5.46	3.82	.832	—14.80
9	—18.36	3.28	1.000	—108.60	—14.97	2.54	1.000	—88.58	—6.59	2.14	.981	—39.00
Average	**— 7.60**	3.05		**— 41.57**	**— 7.96**	3.01		**—34.31**	**—5.92**	2.93		**—24.97**
M. V.	4.41			33.48	2.71			15.52	2.117			8.91
P. E.$_M$ (A)	1.41			10.69	.866			4.96	.676			2.846
Reliability (A)	**1.00**			.995	**1.000**			1.00	**1.000**			1.000
P. E.$_M$ (B)	1.152				1.138				1.107			
Reliability (B)	1.000				1.000				1.000			

[1] This test was not given to the first two non-smokers.

TABLE IX

EFFECT OF TOBACCO ON TREMOR, HABITUAL SMOKERS

Score, number of tremor contacts of stylus in hole during one minute. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 13.5 min.)				Effect, second post-dosage test (after 48.5 min.)				Effect, third post-dosage test (after 1 hr. 23.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	—30.70	9.87	.982	— 72.40	—31.30	8.49	.993	— 73.80	—17.80	7.60	.943	—41.90
11	— 7.16	5.30	.819	— 22.50	—11.66	3.11	.993	— 36.60	— 1.66	4.96	.588	— 5.20
12	—12.53	7.08	.885	— 19.40	— .38	7.21	.514	— .58	+ 4.70	7.12	.672	+ 7.29
13	— 3.32	7.18	.608	— 7.45	+ 4.22	5.98	.682	+ 9.48	+11.93	6.38	.895	+26.80
15	—21.42	3.18	1.000	—182.29	—13.36	2.55	1.000	—113.70	— 1.22	2.22	.645	—10.38
16	—16.59	2.21	1.000	—166.04	—12.36	1.47	1.000	—123.81	— 8.86	1.61	1.000	—88.74
17	— 9.84	3.20	.981	— 37.42	+ 2.04	2.14	.739	+ 7.75	— 1.28	2.50	.635	— 4.84
18	+ 3.27	3.04	.767	+ 10.78	+ 4.54	3.40	.817	+ 14.97	+ 6.88	2.63	.962	+22.69
19	—11.75	3.69	.984	— 46.81	— 5.68	3.37	.873	— 22.62	— 6.51	2.80	9.42	—25.93
Average	**—12.23**	4.97		**— 60.39**	**— 7.104**	4.19		**— 37.65**	**— 1.54**	4.20		**—13.35**
M. V.	7.18			53.23	8.95			44.07	6.38			25.89
P. E.$_M$ (A)	2.02			15.00	2.52			12.41	1.80			7.30
Reliability (A)	**1.00**			.996	**.970**			.98	**.717**			.890
P. E.$_M$ (B)	1.66				1.390				1.400			
Reliability (B)	1.00				1.000				.771			

increase in tremor of the hand. This may be considered as established. The present results indicate in addition that this is as great for habitual smokers as for non-smokers and that for the ordinary smoker, recovery is practically complete an hour and 23 minutes after he has ceased smoking.

CHAPTER V

The Effect of Smoking on the Rate of Voluntary Movement

In the present chapter we pass from the consideration of automatic or involuntary movement to that of the rate of voluntary movement. The method of measurement chosen was the tapping test adapted from Whipple.[1] The tapping board and stylus were tried on some preliminary subjects but is was found unsatisfactory because the stylus frequently became oxidized on the end so that registration was faulty. The instrument finally adopted was a Stoelting round-base telegraph key with the spring set to that it required a pressure of about 500 grams on the button to produce a contact. This key was placed in circuit with four dry cells and the electric counter mentioned above (Chapter IV). As in the steadiness test, the counter was placed behind a small black screen so as to be out of the subject's view. He sat in a swivel chair with his side to the table upon which the key was placed, in such a way that his forearm could rest on the edge of the table if desired. He was directed to tap 400 times as quickly as possible and to go at his maximum speed from the very beginning. Time was taken with a split-second stop-watch, one hand on the watch being stopped when the counter registered 200 taps and the other when it registered 400 taps. In the present chapter we shall consider only the time required for the 400 taps.

A typical set of results in this test is shown in Table X. The construction of the table and the methods of computation are the same as described above, pp. 39 ff. and 49 ff. The final averages with this subject shows a slight loss in speed after smoking but the statistical reliabilities are so low that, with the possible exception of test III, they have no significance. On this one test the chances are about 19 to 1 that a loss in speed has really resulted from the smoking.

[1] Whipple, G. M. Mental and Physical Tests, Simpler Processes, p. 130 ff.

The final results of the investigation of the effect of smoking on rate of tapping are summarized in Tables XI and XII for the non-smokers and the habitual smokers respectively. The minus signs, as usual, mean a loss in efficiency—in this case a retardation in the rate of tapping. A glance at the signs in the body of these

TABLE X

Tapping, subject No. 15, habitual smoker. Score, number of seconds required to make 400 taps with a telegraph key.

	Original scores				Difference between normal of day and subsequent tests			
Control days:	Test I (Normal)	Test II	Test III	Test IV	Test II	Test III	Test IV	Average Difference
Nov. 8	70.6	74	72	72.6	—3.4	—1.4	—2.0	—2.26
" 10	72.6	70.6	69	69.8	+2.0	+3.6	+2.8	+2.80
" 11	73.2	68.4	70.2	73.4	+4.8	+3.0	— .2	+2.53
" 13	72.2	73.4	71.2	72.2	—1.2	+1.0	0.	— .06
" 16	68.6	66.4	66.0	68.8	+2.2	+2.6	— .2	+1.53
" 18	67.4	65.6	65.2	63.8	+1.8	+2.2	+3.6	+2.53
" 19	64.4	64.	66.0	65.6	+ .4	—1.6	—1.2	— .80
" 22	65.2	65.2	64.8	65.8	0.0	+ .4	— .6	— .06
Total	554.2	547.6	544.4	552.0	+6.6	+9.8	+2.2	+6.21
Average	69.27	68.45	68.05	69.0	+ .82	+1.22	+ .27	+ .77
M. V.					1.875	1.625	1.46	1.571
P. E_M					.5604	.4858	.4364	.4695
Tobacco days:								
Nov. 7	73.4	75.0	74.2	76.2	—1.6	— .8	—2.8	—1.73
" 9	72.2	72.2	69.2	69.0	0	+3.0	+3.2	+2.06
" 12	67.2	69.6	71.4	69.6	—2.4	—4.2	—2.4	—3.00
" 14	64.6	67.8	67.4	66.4	—3.2	—2.8	—1.8	—2.60
" 15	66.2	66.4	67.2	64.4	— .2	—1.0	+1.8	+ .20
" 17	62.8	66.2	63.2	64.6	—3.4	— .4	—1.8	—1.86
" 20	65.2	63.4	63.6	61.2	+1.8	+1.6	+4.0	+2.46
" 21	61.4	61.4	62.6	64.6	0	—1.2	—3.2	—1.46
" 23	67.8	63.4	66.4	63.2	+4.4	+1.4	+4.6	+3.46
Total	600.8	605.4	605.2	599.2	—4.6	—4.4	+1.6	—2.47
Average	66.75	67.26	67.24	66.57	— .51	— .49	+ .18	— .27
M. V.					1.901	1.679	2.864	2.062
P. E_M					.5356	.473	.807	.581
Effect of Tobacco:								
Difference					**—1.33**	**—1.71**	**— .09**	**—1.04**
P. E_D					.775	.678	.917	.746
Ratio					1.716	2.522	.100	1.394
Reliability					.8742	.954	.526	.818
Per cent gain or loss					**—1.95**	**—2.51**	**— .13**	**—1.53**

TABLE XI

EFFECT OF TOBACCO ON RATE TAPPING, NON-SMOKERS

Score, the number of seconds required to make 400 taps with a telegraph key. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 30.5 min.)				Effect, second post-dosage test (after 1 hr. 5.5 min.)				Effect, third post-dosage test (after 1 hr. 40.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
1	+3.30	1.110	.977	+5.20	+ .60	1.366	.616	+ .90	+2.20	1.062	.918	+3.50
2	+2.24	.822	.966	+4.40	—3.90	1.240	.981	—7.70	—2.40	1.340	.886	—4.70
3	+ .80	.954	.714	+1.15	—2.90	.984	.967	—3.90	—1.70	.864	.906	—2.46
4	+ .44	.798	.644	+ .76	+ .78	.520	.844	+1.35	+ .44	.564	.700	+ .76
5	— .45	.721	.663	— .70	—1.42	1.118	.804	—2.20	—1.22	1.310	.735	—1.90
6	+ .39	.746	.637	+ .68	—1.15	.880	.809	—2.01	+ .15	.813	.548	+ .26
7	— .98	.342	.973	—1.50	+ .11	.312	.593	+ .17	— .73	.377	.903	—1.18
8	—2.02	1.05	.902	—2.62	+ .23	1.605	.537	+ .30	— .43	1.420	.580	— .56
9	+3.86	1.313	.976	+6.41	+1.23	1.625	.693	+2.04	+1.48	2.060	.686	+2.45
Average	**+ .842**	.873		**+1.53**	**— .71**	1.072		**—1.23**	**— .245**	1.09		**— .425**
M. V.	1.527			2.536	1.448			2.422	1.167			1.927
$P.E._{M}$ (A)	.43			.715	.408			.683	.329			.543
Reliability (A)	**.906**			.926	**.878**			.890	**.693**			.700
$P.E._{M}$ (B)	.291				.357				.363			
Reliability (B)	.974				.910				.669			

tables shows at once that there is little tendency to any definite type of effect. About as many subjects show a gain in efficiency as a loss. The final average of the first post-dosage test with the non-smokers shows a gain in speed of about .8 of a second or about 1.5% whereas the corresponding average for the habitual smokers shows a loss of about the same amount. The reliability of type A in each case is low—approximately 9 to 1—which is the lowest ever used in scientific investigations and below the standard adopted in the present monograph unless supported by other evidence. The reliabilities of type B, on the other hand, are quite satisfactory. This would seem to indicate that there are considerable differences in the reaction of different people to the drug in the processes measured by this test. This view is supported by the considerable number of reliabilities of individual subjects which run up to .900 and above.

The course of the tapping rate throughout the experimental period, was computed and plotted as was done with the corresponding data on the steadiness test. As nothing of significance was revealed, the curves are not reproduced. This computation showed that the habitual smokers, on the average, tapped somewhat slower throughout the experimental period than the non-smokers, the groups requiring 63.3 seconds and 61.9 seconds, respectively. The difference of 1.4 seconds was at first taken to indicate a characteristic difference between the tapping ability of the two groups, but a computation showed that its reliability was only .750. This means that a difference as great as this might happen one time in four by mere chance and that it is not significant.

The previous investigations of the influence of smoking on the rate of tapping have been reviewed above (pp. 8-9). They agree with the present results in showing marked individual differences among the various subjects in the nature of their reaction to the drug. The present writer has found no experimental evidence bearing on the influence of smoking on the habitual smokers, unless Johnson's subjects were of that type. If they were, his results, so far as they go, agree with those of the present investigation in showing a slight loss in efficiency. Froeberg's results, which alone in this field are sufficiently numerous to be worthy of serious con-

TABLE XII

EFFECT OF TOBACCO ON RATE OF TAPPING, HABITUAL SMOKERS

Score, number of seconds required to make 400 taps with a telegraph key. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 30.5 min.)				Effect, third post-dosage test (after 1 hr. 5.5 min.)				Effect, third post-dosage test (after 1 hr. 40.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	—3.40	1.32	.959	—5.62	—3.70	1.33	.970	—6.12	+2.96	1.92	.850	+4.90
11	—1.40	.60	.940	—2.70	— .87	.77	.781	—1.70	—1.47	.80	.890	—2.90
12	—1.92	.72	.964	—3.14	—2.27	1.22	.895	—3.72	— .32	.63	.635	— .52
13	—4.65	.96	.994	—7.47	+1.09	1.29	.717	+1.73	+ .19	.98	.551	+ .30
14	—1.33	.78	.874	—1.95	—1.71	.68	.954	—2.51	— .09	.92	.526	— .13
15	+ .61	.67	.729	+ .92	+1.46	.72	.911	+2.20	+ .92	.89	.756	+1.38
16	+ .49	.36	.820	+ .76	— .48	.52	.735	— .74	— .79	.48	.867	—1.22
17	+1.32	.65	.915	+1.83	— .02	.96	.505	— .02	—1.03	.77	.817	—1.43
18	+1.90	.77	.952	+2.94	+1.14	.79	.834	+1.76	+2.63	.65	.997	+4.08
Average	**— .93**	.76		**—1.60**	**— .60**	.92		**—1.01**	**+ .33**	.89		**+ .50**
M V.	1.79			2.86	1.37			2.22	1.22			1.97
P. $E._{M}$ (A)	.50			.81	.39			.63	.34			.56
Reliability (A)	**.894**			.906	**.852**			.860	**.739**			.729
P. $E._{M}$ (B)	.25				.31				.30			
Reliability (B)	.994				.910				.771			

sideration, show an average gain of 1.6% with non-smokers. This is in almost exact agreement with the corresponding results with our own non-smokers. This obviously strengthens considerably the somewhat meagre statistical reliability of our own results with this class of subjects. We may conclude then, that some 30 minutes after smoking, there is a fair probability that non-smokers as a group show a slight stimulation in rate of tapping. The evidence is somewhat weaker that habitual smokers show an equally slight loss in speed of tapping. The effect, if any, of habituation, is thus to reverse the effect of the drug. At the end of an hour all trace of either effect is quite lost. Lastly, all available results alike show striking disagreements among the various subjects as to the nature of the individual effects of tobacco smoking as measured by this test.

CHAPTER VI

The Effect of Smoking on Muscular Fatigue

In the last chapter it was pointed out that the time required for the subject to make the first 200 taps was recorded along with that for the 400. This was done for the purpose of securing a measure of muscular fatigue. If a subject starts tapping at his maximum speed, he will ordinarily require longer for his second 200 taps than for his first 200. Accordingly, if we multiply the time required for the first 200 by 2 and subtract the results from the time required by the 400, the difference will be the length of time that the second 200 taps required over that consumed by the first. This difference, then, becomes a convenient measure of the amount of fatigue produced by the activity in question. While doubtless not yielding results exactly comparable with those obtained by the ergograph, the method does yield a measure of a certain kind of fatigue of rapid onset, and has the distinct advantage or requiring no additional effort or time from either the subject or the experimenter. Indeed, if it had been necessary to introduce a special test for the purpose, no data on muscular fatigue could have been secured at all.

The fatigue results of the typical subject are shown in detail in Table XIII. The construction of this table and the various computations are similar to the corresponding ones in previous chapters. It will be seen that this subject shows a distinctly better resistance to fatigue after smoking than after the control dose.

The results of the entire investigation of the effect of smoking on muscular fatigue are shown in Tables XIV and XV for the non-smokers and the habitual smokers, respectively. It will be noted that the results of one subject in each group are lacking because of the inadequacy of the stop-watch used on those occasions. The final averages of these tables are supplemented by the curves of Figs. 6 and 7. These show for the respective groups of subjects the average course of the fatigue throughout the experimental period for the control days and the tobacco days in parallel.

The most striking effect of smoking revealed by this set of data is the greatly strengthened resistance to fatigue among the non-smokers. On the first post-dosage test, there isn't a single negative sign among these subjects and the statistical reliability indicates

TABLE XIII

Muscular fatigue, subject No. 15, habitual smoker. Score, number of seconds required to make the second 200 taps in excess of the number required for the first 200 taps.

	Original scores				Difference between normal of day and subsequent tests			
	Test	Test	Test	Test	Test	Test	Test	Average
Control	I	II	III	IV	II	III	IV	Difference
days:	(Normal)							
Nov. 8	4.2	2.4	4.0	.6	+ 1.8	+ .2	+ 3.6	+ 1.86
" 10	1.8	4.2	3.4	1.8	— 2.4	— 1.6	0	— 1.33
" 11	6.4	5.2	3.4	1.8	+ 1.2	+ 3.0	+ 4.6	+ 2.93
" 13	3.0	3.0	3.6	2.2	0	— .6	+ .8	+ .06
" 16	1.8	1.6	2.4	.4	+ .2	— .6	+ 1.4	+ .33
" 18	1.0	4.0	2.8	2.6	— 3.0	— 1.8	— 1.6	— 2.13
" 19	1.6	3.6	1.6	2.8	— 2.0	0	— 1.2	— 1.06
" 22	2.0	1.2	2.0	3.8	+ .8	0	— 1.8	— .33
Total	21.8	25.2	23.2	16.0	— 3.4	— 1.4	+ 5.8	+ .33
Average	2.72	3.15	2.9	2.0	— .42	— .17	+ .72	+ .04
M. V.					1.53	.98	1.88	1.25
P. E.$_M$					.46	.29	.56	.37
Tobacco days:								
Nov. 7	2.2	3.4	2.2	1.0	— 1.2	0	+ 1.2	0
" 9	5.0	2.2	3.0	1.8	+ 2.8	+ 2.0	+ 3.2	+ 2.66
" 12	2.8	2.0	1.4	.4	+ .8	+ 1.4	+ 2.4	+ 1.53
" 14	3.8	2.2	3.8	1.6	+ 1.6	0	+ 2.2	+ 1.26
" 15	4.2	3.2	.8	.8	+ 1.0	+ 3.4	+ 3.4	+ 2.60
" 17	3.2	1.0	2.0	2.6	+ 2.2	+ 1.2	+ .6	+ 1.33
" 20	2.0	2.2	2.0	2.0	— .2	0	0	— .06
" 21	4.6	3.4	3.8	2.2	+ 1.2	+ .8	+ 2.4	+ 1.46
" 23	3.4	4.6	2.8	3.2	— 1.2	+ .6	+ .2	— .13
Total	31.2	24.2	21.8	15.6	+ 7.0	+ 9.4	+15.6	+10.65
Average	3.46	2.68	2.42	1.73	+ .78	+ 1.04	+ 1.73	+ 1.18
M. V.					1.10	.85	1.10	.83
P. E.$_M$					.31	.24	.31	.23
Effect of Tobacco:								
Difference					+ 1.20	+ 1.21	+ 1.01	+ 1.14
P. E.$_D$					.55	.38	.64	.44
Ratio					2.18	3.18	1.58	2.59
Reliability					.927	.983	.859	.96
Per cent gain or loss					+38.83	+39.15	+32.68	+36.99

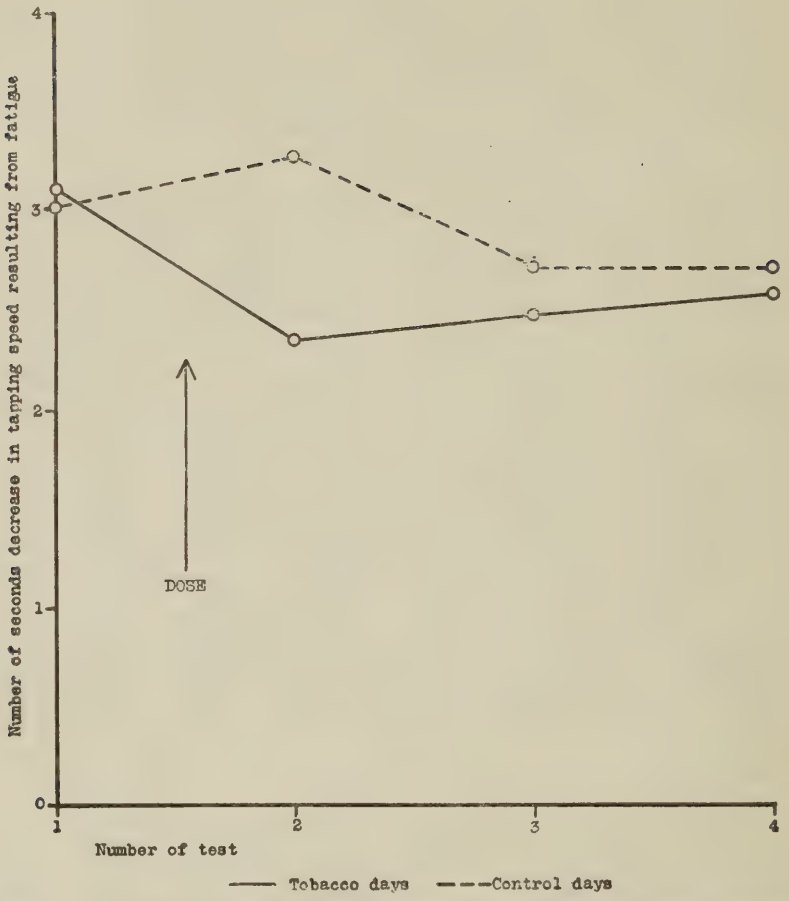

FIG. 6. The effect of smoking on muscular fatigue resulting from tapping with a telegraph key, non-smokers.

that there is less than one chance in a hundred that it does not indicate a real difference in favor of the tobacco days. The curves of Fig. 6 confirm this by their marked divergence following the dose. By the end of the experimental period, however, the curves have nearly come together again, showing that after an hour and 40 minutes the special resistance has practically disappeared.

In the case of the habitual smokers, there appears also to be an increased resistance to fatigue after smoking, though it is distinctly less in amount and probably disappears somewhat more quickly

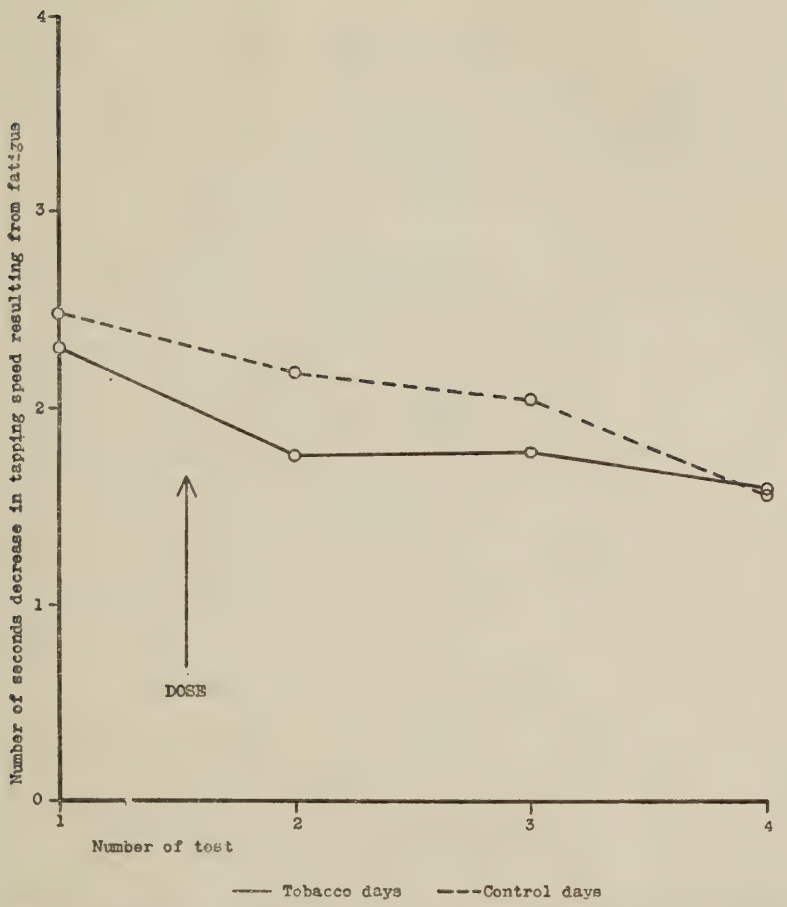

FIG. 7. The effect of smoking on muscular fatigue resulting from tapping with a telegraph key, habitual smokers.

than with the non-smokers. The statistical reliability of the difference in this case is clearly below the standard adopted in the present investigation but it is so strongly supported by other considerations that it may be accepted with a fair amount of confidence. In the first place, the curves of Fig. 7 show about twice as great a separation as the averages from the corresponding table would lead one to expect. The reason for this apparent discrepancy between the table and the curves lies in the separation of the two curves at

TABLE XIV

EFFECT OF TOBACCO ON MUSCULAR FATIGUE, NON-SMOKERS

Score, number of seconds required to make the second 200 taps in excess of the number required for the first 200 taps. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 30.5 min.)				Effect, second post-dosage test (after 1 hr. 5.5 min.)				Effect, third post-dosage test (after 1 hr. 40.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
1	.00	.428	.000	.00	—1.04	.815	.804	—39.90	—1.32	1.16	.774	—48.10
2[1]	—	—	—	——	—	—	—	——	—	—	—	——
3	+ .45	.604	.691	+10.60	+1.02	.644	.856	+24.10	+1.19	.553	.926	+28.10
4	+ .56	.524	.762	+18.60	+ .41	.428	.739	+13.60	— .18	.498	.596	— 6.00
5	+ .11	.808	.535	+ 2.38	+1.89	.698	.965	+41.00	.00	.986	.000	.00
6	+ .40	.569	.681	+10.40	— .89	.440	.912	—23.10	— .27	.626	.614	— 7.00
7	+ .77	.362	.923	+25.30	+ .60	.303	.909	+19.70	+ .05	.358	.573	+ 1.60
8	+ .90	.729	.796	+30.60	— .41	.724	.648	—13.90	+ .20	.717	.574	+ 6.80
9	+4.72	1.148	.997	——	+ .93	1.035	.727	——	+1.87	1.498	.799	——
Average	**+ .99**	.646		**+32.20**[2]	**+ .31**	.635		**+10.10**	**+ .19**	.799		**+ 6.20**
M. V.	.933				.820				.670			
P. E.$_M$[(A)]	.279				.245				.200			
Reliability[(A)]	**.990**				**.800**				**.739**			
P. E.$_M$[(B)]	.228				.224				.282			
Reliability[(B)]	.998				.827				.669			

[1] The fatigue scores with this subject are not reliable because of an inadequate stop-watch.

[2] The percentage effect is not given for subject 9 because through a habit picked up in athletic contests, he reserved his best efforts for the last with the result that there was practically a zero amount of fatigue previous to the dose. This would so distort the *percentage* effect that it would be without meaning. For this reason the percentage effects of the final average is computed by dividing the average difference caused by the smoking by the average of the tests preceding the dose. As the result of this, no P. E.'s and no reliabilities appear for these averages.

TABLE XV

EFFECT OF TOBACCO ON MUSCULAR FATIGUE, HABITUAL SMOKERS

Score, number of seconds required to make the second 200 taps in excess of the number required for the first 200 taps. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 30.5 min.)				Effect, second post-dosage test (after 1 hr. 5.5 min.)				Effect, third post-dosage test (after 1 hr. 40.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	[1]											
11	+ .05	.35	.538	+ 3.80	+ .45	.35	.806	+34.20	+1.19	.71	.870	+90.40
12	— .71	.54	.812	—16.00	+ .36	.56	.660	+ 8.10	—1.35	.56	.948	—30.50
13	+1.23	.59	.919	+42.20	+ .70	.92	.693	+24.00	+ .65	.85	.693	+22.30
15	+1.20	.55	.927	+38.80	+1.21	.38	.983	+39.20	+1.01	.64	.859	+32.70
16	+ .51	.68	.691	+13.50	—1.01	.60	.874	—26.73	—2.43	1.31	.894	—64.50
17	— .37	.29	.806	—19.27	— .30	.27	.773	—15.62	— .84	.26	.985	—43.75
18	+ .11	.38	.578	+ 7.18	— .46	.51	.729	—30.46	+ .62	.45	.823	+41.05
19	— .16	.41	.604	——	— .20	.53	.601	——	—1.23	.77	.860	——
Average	+ .23	.47		+10.03	+ .09	.51		+ 3.70	— .30	.69		—12.50
M. V.	.56				.586				1.16			
$P. E._{M}$ (A)	.17				.180				.35			
Reliability (A)	.818				.632				.717			
$P. E._{M}$ (B)	.170				.180				.250			
Reliability (B)	.827				.632				.791			

[1] The fatigue results of this subject were not obtained because of an inadequate stop-watch.

[2] The percentage effects of subject 19 were not computed because the normal amount of fatigue was so small that the result would have been quite without meaning. For this reason the percentage effects of the final average is computed by dividing the average difference caused by smoking by the average of the tests preceding the dose. Because of this, no P. E.'s and no reliabilities are computed for these averages.

their point of origin, whereas theoretically (i.e., except from chance sampling errors) they should start from the same point. The above view also finds support in the characteristic subsequent course of the curves as well as in the general probability of a reduction in effect of a drug resulting from habituation.

It will also be noted in Figures 6 and 7 that the habitual smokers show throughout, a smaller amount of fatigue than the non-smokers. On the normal performances preceding the dose, the non-smokers show on the average nearly .7 of a second more fatigue than the habitual smokers, which amounts to over 21 per cent. The statistical reliability of this result is .852, which indicates that the chances are about 6 to 1 that there probably is a real difference between the two groups in favor of the habitual smokers. It is true that this reliability unsupported by other considerations is not sufficient to base action upon but as we shall encounter similar differences from time to time throughout the present study, a number of possible explanations may profitably be considered at this time. It is conceivable, for example, that in the case of the habitual smokers the immunizing effect of the last smoke of the day preceding the experiment may have lingered long enough to make them less susceptible to fatigue than the non-smokers. But this hypothesis is at once negatived by the fact that the immunity which results from the smoking during the experiment itself is lost within a couple of hours after smoking, whereas these subjects had not smoked for 3 hours or more preceding the test in question. A second possibility it that the continued use of tobacco may have produced a lasting tendency to immunity in the habitual smokers, making them more or less permanently superior to non-smokers in this respect. The writer inclines, however, to explain the difference on the assumption that the smokers were a selected group. They appear to have been somewhat more easy-going as a group than the non-smokers and possibly did not put quite so much effort into the tapping. In this connection it may be recalled that the habitual smokers tapped, on the average, slightly slower than the non-smokers. This would naturally produce less fatigue. The selective factor referred to was the choice of subjects for this group who were, so far as possible, exclusively pipe smokers but from a population composed almost entirely of cigarette smokers.

We may now summarize the results of the investigation as follows:

1. Non-smokers show unmistakably greater resistance to fatigue in tapping as a result of smoking.

2. This immunity to fatigue is gradually lost so that 1 hour and 40 minutes after smoking, only a trace remains.

3. Habitual smokers as a group also show an increase in resistance to fatigue after smoking, though it is less in amount and disappears more quickly than with the non-smokers.

4. Habituation thus appears to produce a partial tolerance to this action of tobacco.

5. On the normal tests preceding the dose, the habitual smokers as a group show less fatigue than the non-smokers. This is thought to be due in some way to the factor of selection.

The evidence from previous investigations as to the effects of smoking on muscular fatigue with human subjects, has been summarized above, pp. 9-11. The bearing of these experiments on the results of the present investigation are somewhat uncertain owing to differences in technique. The investigations in question have used one form or another of the ergograph. This yields a score primarily in terms of the strength of muscular contraction at constant rate, whereas the score in the present investigation is in terms of the rate of contractions at constant strength with the latter well below the fatigue level. Moreover, the fact that the investigations in question are based on such a small number of data introduces additional complications. All 4 studies taken together employ a total of only 5 subjects. Lastly there is little agreement among these studies as to results obtained. One of them shows a definite loss in efficiency, two show no reliable effect and one shows a fairly definite advantage. Of the 4 investigations the technique of Hough differs least from that used here. He employed a spring ergograph and took as a measure of fatigue the rapidity of the fall of the work curve which is substantially the present method of scoring. He found exactly as in the present study, that smoking enabled him to resist the onset of fatigue considerably better than when he did not smoke.

Hough states in discussing the bearing of his results on muscular

fatigue in general, that certain individuals at least, are enabled to bear fatiguing work more easily by the use of tobacco.[1]

In the light of all the available evidence, then, we may say that the present results indicate pretty definitely that the early part of one type of work curve falls off less rapidly after smoking than when the subject has not smoked. The present investigation tells us nothing positively about the subsequent course of the curve though there is some presumption that it follows the same tendency. There is some corroborative experimental evidence from a single subject (Hough) in support of this view, as well as a certain popular beliefs. There is, on the other hand, some experimental evidence from a single subject (Lombard) which conflicts with it. It is therefore unsafe to draw any positive conclusions at this time as to the influence of tobacco on the onset of fatigue for muscular work in general. In view of the inadequate and conflicting nature of the ergographic results reported thus far, the present investigation serves at least to call seriously in question the statements prevalent in the propagandist literature, that tobacco greatly reduces resistance to fatigue. The matter needs a careful and thorough investigation at the hands of trained physiologists.

[1] In this connection we may also recall rumors current during the late war to the effect that soldiers under the necessity of exerting themselves to the maximum for protracted periods, were enabled to a large extent to resist the normal onset of fatigue by the smoking of cigarettes. This may have been propaganda, however.

CHAPTER VII

The Effect of Smoking on the Rate of Cancelling A's

In the present chapter we pass from the processes mainly physiological to those in which the emphasis is primarily psychological. The A-test presents on the psychological level a measure of visual acuity and discrimination, combined on the physiological level with a measure of the rapidity of relatively simple movements of the hand. The test thus involves the elements of much of the repetitive work of the modern factory and the results have a little special interest because of this. The printed material for this part of the investigation became available only after the first 7 of the non-smokers had been tested so that the results to be reported apply primarily to the habitual smokers in whom, fortunately, our interest mainly centers.

The form of the A-test employed is reproduced in Appendix K, and contains 100 A's. It is an adaptation of a form in wide use.[1] Eight different forms of this test were specially printed but with no external evidence to distinguish any of them from the rest. In order to make all eight forms equal in difficulty they were made up in such a way that each line of each of the eight forms had the same number of the various letters in it as the corresponding lines of the other forms, only the different lines were arranged differently in each form according to chance drawings. Likewise the order of the letters in the respective lines were differently arranged in the different forms according to chance. The trouble and expense of preparing and printing so many forms of this test were undertaken in order, so far as possible, to prevent the subjects from gradually learning the positions of the A's on the test blank. If this had taken place, the test would gradually have lost its discriminatory nature and have degenerated into something like a test of the rate of voluntary movement. As a further precaution in the same direction, no intimation was given the subjects that the same form of

[1] Whipple, G. M. Mental and Physical Tests. Simpler Processes, p. 307.

the test was ever repeated, though as a matter of fact each form always was repeated 9 times during the 18 days. That the method succeeded is indicated by the fact that introspections taken from a number of subjects at the end of their last day in the experiment

TABLE XVI

Cancellation, subject No. 15, habitual smoker. Score, number of A's cancelled in one minute plus half the A's for which a mark was made but failed to touch the letter.

	Original scores				Difference between normal of day and subsequent tests			
	Test	Test	Test	Test	Test	Test	Test	Average
Control	I	II	III	IV	II	III	IV	Difference
days:	(Normal)							
Nov. 8	69	76	76.5	68.5	+ 7.0	+ 7.5	— .5	+ 4.66
" 10	77	72	78.0	77	— 5.0	+ 1.0	0	— 1.33
" 11	78.5	69	72.5	76	— 9.5	— 6.0	— 2.5	— 6.00
" 13	71.5	78	79.0	78	+ 6.5	+ 7.5	+ 6.5	+ 6.83
" 16	75.5	76	76.5	71.5	+ .5	+ 1.0	— 4.0	— .83
" 18	69.0	72.5	80.0	76	+ 3.5	+11.0	+ 7.0	+ 7.16
" 19	77.5	81.5	74.5	76	+ 4.0	— 3.0	— 1.5	— .16
" 22	79.5	81	75.5	72.5	+ 1.5	— 4.0	— 7.0	— 3.16
Total	597.5	606	612.5	595.5	+ 8.5	+15.0	— 2.0	+ 7.16
Average	74.69	75.75	76.56	74.43	+ 1.06	+ 1.87	— .25	+ .895
M. V.					4.30	5.09	3.56	3.990
P. E_M					1.28	1.52	1.06	1.190
Tobacco days:								
Nov. 7	68.5	68.5	64	70	0	— 4.5	+ 1.5	— 1.00
" 9	75	73	74.5	73.5	— 2.0	— 0.5	— 1.5	— 1.33
" 12	78	79	83	83	+ 1.0	+ 5.0	+ 5.0	+ 3.66
" 14	79	79	76.5	73	0.	— 2.5	— 6.0	— 2.83
" 15	76.5	79.5	82	73	+ 3.0	+ 5.5	— 3.5	+ 1.66
" 17	71.0	80	81	79	+ 9.0	+10.0	+ 8.0	+ 9.00
" 20	81.5	69	80	83	—12.5	— 1.5	+ 1.5	— 4.16
" 21	87	83.5	79	78.5	— 3.5	— 8.0	— 8.5	— 6.66
" 23	82	77	73.5	73.5	— 5.0	— 8.5	— 8.5	— 7.33
Total	698.5	688.5	693.5	686.5	—10.0	— 5.0	—12.0	— 9.00
Average	77.61	76.5	77.05	76.28	— 1.11	— .55	— 1.33	— 1.00
M. V.					4.12	4.94	4.74	3.85
P. E_M					1.16	1.39	1.34	1.08
Effect of Tobacco:								
Difference					— 2.17	— 2.42	— 1.08	— 1.895
P. E_D					1.73	2.06	1.71	1.61
Ratio					1.25	1.17	.63	1.18
Reliability					.8004	.781	.6571	.781
Per cent gain or loss					— 2.85	— 3.18	— 1.42	— 2.49

revealed no case where a man had even noticed the second appearance of any form of the test.

In order to eliminate any constant errors due even to an unconscious tendency to learn the positions of the A's, the various forms were given in a constantly but systematically varying order yet one such that on any given experimental day all four forms used had previously received the same amount of practice. There was, of course, a great deal of improvement in speed of cancellation from ordinary practice effects, but this was a factor not likely to introduce any important change into the nature of the test such as learning the positions of the A's would have done. Constant errors due to practice effects were automatically eliminated by features of the technique previously discussed (p. 38).

The form of giving the test was as follows:

The subject was given a special blue pencil and a test blank was placed face down on the table before him. He was instructed that at the signal "Go" he was to turn over the sheet and cancel out the A's as rapidly and accurately as possible until told to stop. One minute was ordinarily allowed. On the latter days of the tests, some subjects became so rapid that there was danger that they might finish before the expiration of the allotted time. In such cases the time limit was reduced to 50 seconds, the time being constant throughout any given experimental day. As an added precaution, the reduction of the time was made at such a point in the experiment that there would be an equal number of control and tobacco days affected by it, though the methods of computation and control probably made this unnecessary. The score was the number of A's cancelled plus half of the A's for which a mark was made but failed to touch the letter. In this score no deductions were made for errors. These will be considered separately in the next chapter. A special set of 8 celluloid stencils for scoring the various forms was made by stamping out squares over each A on a given blank. These aided greatly in the speed and accuracy of the scoring, particularly in the case of the errors.

The cancellation results of the typical subject appear in Table XVI. The construction of this table and the various computations are exactly as described above, pp. 39 ff. and 49 ff. This subject

TABLE XVII

EFFECT OF TOBACCO ON CANCELLATION TEST, NON-SMOKERS

Score, number of A's cancelled in one minute plus half the A's for which a mark was made but failed to touch the letter. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 16 min.)				Effect, second post-dosage test (after 51 min.)				Effect, third post-dosage test (after 1 hr. 26 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
[1]												
8	+ .64	1.046	.659	+ .78	—1.20	1.677	.648	—1.45	—1.33	1.610	.710	—1.61
9	—1.77	1.940	.731	—2.26	—5.50	1.700	.985	—7.02	— .03	1.980	.504	— .04
Average	— .565	1.493		— .79	—3.35	1.685		—4.235	— .63	1.795		— .825
M. V.												
$P. E._{M}$ (A)												
Reliability (A)												
$P. E._{M}$ (B)	1.055				1.193				1.269			
Reliability (B)	.640				.970				.632			

[1] This test was not given to the first seven non-smokers.

TABLE XVIII

EFFECT OF TOBACCO ON CANCELLATION TEST, HABITUAL SMOKERS

Score, number of A's cancelled in one minute plus half the A's for which a mark was made but failed to touch the letter. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 16 min.)				Effect, second post-dosage test (after 51 min.)				Effect, third post-dosage test (after 1 hr. 26 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	—1.56	1.91	.709	—2.54	—1.47	1.43	.754	—2.40	+ .29	1.66	.545	+ .47
11	+3.17	2.16	.836	+4.80	+1.00	1.47	.681	+1.50	—3.25	2.02	.860	—4.90
12	—2.19	1.47	.863	—2.60	—2.28	1.47	.858	—2.80	+ .11	1.79	.516	+ .13
13	—3.39	1.88	.890	—4.20	—4.65	2.94	.852	—5.8	—3.11	1.79	.881	—3.90
15	—2.17	1.73	.800	—2.85	—2.42	2.06	.781	—3.18	—1.08	1.71	.657	—1.40
16	+2.78	1.93	.831	+3.36	+ .27	1.33	.544	+ .32	— .86	1.89	.619	—1.04
17	+1.35	1.62	.712	+1.50	— .89	1.34	.672	— .99	+ .75	2.02	.599	+ .83
18	— .19	1.47	.535	— .21	— .49	2.64	.551	— .55	—3.15	1.95	.863	—3.54
19	+3.10	1.46	.923	+3.88	+2.59	1.25	.919	+3.25	+ .42	1.65	.567	+ .52
Average	**+ .10**	1.74		**+ .13**	**— .93**	1.77		**—1.18**	**—1.10**	1.83		**—1.42**
M. V.	2.22			2.89	1.58			2.10	1.38			1.79
$P.E._M$ (A)	.63			.81	.45			.59	.39			.50
Reliability (A)	**.542**			.540	**.917**			.911	**.970**			.970
$P.E._M$ (B)	.580				.59				.610			
Reliability (B)	.540				.852				.890			

shows a slight loss in speed of cancellation after smoking, but the reliability of the difference is so low that, standing by itself, it has no significance.

The final results of the two non-smokers are shown in Table XVII and of the habitual smokers in Table XVIII. In addition, the average course of the rate of cancellation throughout the experimental day was computed for the smokers for both control and tobacco days and plotted in parallel. Nothing of importance was revealed, however, and as the differences involved were too minute to show well on a graph of ordinary size, they are not reproduced.

The results of the non-smokers are too few to be of much significance, though, so far as they go, they suggest a slight loss in efficiency as a result of smoking. The habitual smokers show little agreement among themselves as to the nature of the effect and none of them shows a satisfactory individual reliability. Turning to the averages of the entire group we find that on the first post-dosage test (16 min.) there is practically a zero effect. At 51 minutes there appears a minute loss of about 1 per cent and at 1 hour and 26 minutes, this loss shows a slight increase. Small as it is, the effect in the last case mentioned has a statistical reliability reaching the lower limits adopted in the present investigation as satisfactory. This would seem to indicate that, within the limits covered by the present investigation, tobacco has a very slight inhibiting action on the speed of cancellation. It may or may not be significant that the loss in efficiency increases continuously throughout the post-dosage period. So far as the non-smokers go, they also suggest a similar tendency.

The final discussion and evaluation of the above results will be deferred until the end of the following chapter.

CHAPTER VIII

The Effect of Smoking on the Accuracy of Cancelling A's

The technique of the A-test has been described in detail in Chapter VII. In addition to the score of correct cancellations secured from each test record, there was also obtained a score of errors. These errors were of three kinds: (1) the A's overlooked, (2) the number of other letters incorrectly cancelled, and (3) the A's where a stroke of the pencil was made with the evident intention of cancellation but where the mark failed to touch any part of the A. Each of these last was arbitrarily scored as ½ an error. The major part of the errors was of type (1). Despite their different nature, all three types of error were massed together without distinction in the tables because the number of errors of any one type would have been too small for profitable statistical treatment. Indeed, with some subjects this was almost the case where all three were combined. The average score of all errors combined for the smoker subjects on the normal tests preceding the dose, was less than 2 per minute.

The complete results from the typical subject on errors in cancellation are shown in Table XIX. The construction of the table and the various computations are exactly as described above, pp. 39 ff. This subject shows a tendency to an increase in accuracy as the result of smoking throughout the period. On the first post-dosage test the effect becomes large enough to obtain a satisfactory statistical reliability.

The final results of the two non-smokers appear in Table XX and those for the habitual smokers are shown in Table XXI. As in chapter VII, the data from the non-smokers are too few to be of more than suggestive value. So far as this evidence goes, it points to a loss in accuracy as the result of smoking. The habitual smokers show a great lack of agreement among themselves as to the nature of the effect produced just as in the chapter on the rate of cancellation. The final averages of all the subjects in this case,

however, show a slight gain in efficiency as the result of smoking instead of a loss, though in no case does the amount of gain quite reach the level of statistical reliability adopted in the present investigation as satisfactory. On the second and third post-dosage

TABLE XIX

Errors in cancellation, subject No. 15, habitual smoker. Score, number of A's omitted plus the number of other letters cancelled plus half the strokes which failed to reach the mark.

	Original score				Difference between normal of day and subsequent tests			
Control days:	Test I (Normal)	Test II	Test III	Test IV	Test II	Test III	Test IV	Average Difference
Nov. 8	5	7	2	3	— 2	+3	+ 2	+ 1.00
" 10	4	4	2	2	0	+2	+ 2	+ 1.33
" 11	3	2	2	3	+ 1	+1	0	+ .66
" 13	2	2	3	4	0	—1	— 2	— 1.00
" 16	2	3	2	3	— 1	0	+ 1	— .66
" 18	3	2	3	2	+ 1	0	+ 1	+ .66
" 19	4	6	1	2	— 2	+3	+ 2	+ 1.00
" 22	2	2	5	5	0	—3	— 3	— 2.00
Total	25	28	20	24	— 3	+5	+ 1	+ 1.00
Average	3.12	3.5	2.5	3.0	— .37	+ .62	+ .12	+ .125
M. V.					.968	1.63	1.63	1.000
P. E_M					.289	.487	.487	.299
Tobacco days:								
Nov. 7	5	6	3	3	— 1	+2	+ 2	+ 1.00
" 9	8	0	6	1	+ 8	+2	+ 7	+ 5.66
" 12	5	2	4	2	+ 3	+1	+ 3	+ 2.33
" 14	0	2	3	2	— 2	—3	— 2	— 2.33
" 15	5	4	1	3	+ 1	+4	+ 2	+ 2.33
" 17	3	0	0	2	+ 3	+3	+ 1	+ 2.33
" 20	1	2	1	0	— 1	0	+ 1	0
" 21	5	2	2	8	+ 3	+3	— 3	+ 1.00
" 23	2	2	6	7	0	—4	— 5	— 3.00
Total	34	20	26	28	+14	+8	+ 6	+ 9.33
Average	3.77	2.22	2.88	3.11	+ 1.55	+ .88	+ .66	+ 1.04
M. V.					2.39	2.15	2.67	1.89
P. E_M					.673	.606	.752	.532
Effect of Tobacco:								
Difference					1.92	+ .26	+ .54	+ .91
P. E_D					.735	.78	.89	.61
Ratio					2.610	.34	.61	1.50
Reliability					.961	.593	.657	.844
Per cent gain or loss					+55.65	+7.53	+15.65	+26.37

TABLE XX

EFFECT OF TOBACCO ON ERRORS IN CANCELLATION TEST, NON-SMOKERS

Score, the number of A's omitted plus the number of other letters cancelled plus ½ the the strokes which failed to reach the mark. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 16 min.)				Effect, second post-dosage test (after 51 min.)				Effect, third post-dosage test (after 1 hr. 26 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
8	—.33	.124	.963	—183.30	—.21	.179	.784	—116.70	—.36	.124	.974	—200.00
9	—.12	.140	.716	— 70.60	+.03	.194	.540	17.60	—.12	.140	.716	— 70.60
Average	**—.225**	.132		**—126.90**	**—.09**	.186		**— 49.60**	**—.24**	.132		**—135.30**
M. V.												
$P.E._{M}$ (A)												
Reliability (A)												
$P.E._{M}$ (B)	.093				.132				.093			
Reliability (B)	.948				.680				.958			

TABLE XXI

EFFECT OF TOBACCO ON ERRORS IN CANCELLATION TEST, HABITUAL SMOKERS

Score, the number of A's omitted plus the number of other letters cancelled plus ½ the strokes which failed to reach the mark. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 16 min.)				Effect, second post-dosage test (after 51 min.)				Effect, third post-dosage test (after 1 hr. 26 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	— .90	.519	.879	— 46.10	— .34	.432	.702	+ 17.40	—1.37	.578	.945	—70.20
11	+ .83	.689	.790	+ 45.30	+1.66	.789	.922	+ 90.70	+1.16	.622	.894	+63.30
12	+ .44	.320	.827	+ 85.40	+ .21	.340	.657	+ 40.70	— .15	.370	.606	—29.10
13	+ 2.66	1.390	.901	+ 70.70	+2.72	1.370	.911	+ 72.30	+3.73	1.660	.935	+99.20
15	+1.92	.740	.961	+ 55.65	+ .26	.780	.593	+ 7.53	+ .54	.890	.657	+15.65
16	+ .616	.660	.732	+ 27.40	+ .45	.640	.682	+ 20.22	+1.79	.650	.967	+79.51
17	— .04	.390	.527	— 2.28	+1.87	.370	.999	+106.85	+1.40	.450	.982	+80.00
18	— .65	.460	.829	— 51.18	— .48	.470	.754	— 37.79	— .17	.390	.614	—13.38
19	— .97	.330	.976	—149.23	— .76	.360	.923	—116.92	— .23	.490	.622	—35.38
Average	+ **.43**	.62		+ **3.96**	+ **.62**	.62		+ **18.47**	+ **.75**	.68		+**21.06**
M. V.	.96			57.81	.97			52.99	1.14			52.83
P. E.$_M$ (A)	.27			16.29	.27			14.93	.32			14.89
Reliability (A)	**.844**			.567	**.939**			.80	**.940**			.828
P. E.$_M$ (B)	.210				.210				.230			
Reliability (B)	.916				.977				.986			

tests with this group, the chances are about 15 to 1 that smoking really increases the accuracy of cancellation. It may also be significant that this average gain in accuracy increases from test to test very much as the speed of cancellation decreased from test to test with the same subjects. It should be noted in addition that this gain in accuracy is almost the same in amount as the loss in speed.

The only investigation of the effect of smoking on cancellation found by the present writer is that of Bush. This study has been reviewed in some detail above (p. 11 ff.). Bush reports an average loss in speed of 17 per cent with a squad of subjects composed mostly of habitual smokers. He gives no results as to accuracy. The difference between the 17 per cent loss found by Bush and the 1 per cent or less found in the present investigation is really enormous and demands serious consideration. There are a number of differences in technique which might have contributed to this difference. Bush's material was unspaced prose as distinguished from the random letters used by the writer. Of more importance, his tests before smoking were on E's and after smoking were on A's, the assumption evidently being that the two letters were equally easy to cancel. Moreover, his subjects smoked only about half as long as those in the present experiment. He neglects to state how long after the smoking this test was given, but there is some indication that it was given immediately, whereas the present test was given 16 minutes after. In this connection it may be recalled that what little loss in speed is found in the present investigation appears only after an hour or more. The present writer inclines to attribute the difference found more to certain defects in Bush's general technique such as the lack of a suitable control which have been pointed out by Froeberg and reviewed above, p. 12 ff.

Ultimately, an issue of this kind must be decided by further and more careful experimentation. Meanwhile, so far as the present investigation goes, it indicates either that tobacco has no measurable effect whatever on the cancellation of habitual smokers, or if it has any effect, it makes them a trifle more careful in their work which increases their accuracy slightly but at the sacrifice of an equally slight loss in speed.

CHAPTER IX

The Effect of Smoking on the Speed of Oral Reading of Isolated Words

The next process to be investigated in our advance from the lower to the higher mental processes, is the effect of smoking on the rapidity of the functioning of thoroughly formed sensory-motor associative bonds of long standing. Few associations are more firmly established than that between the visual stimulus and the speech reaction in reading. Accordingly 30 common four-letter unrelated words were selected to be read orally. one at a time. The words were: *wood, loaf, zinc, heel, shop, home, back, drug, wolf, kite, horn, gold, hand, hole, fish, cape, park, coat, cake, bear, lamp, boat, cool, frog, page, bird, song, bead, girl, duck.*

They were carefully typed on stiff paper which was later cut up in such a way that each word was in the middle of a card about an inch square. These cards were then attached in a chance order to a specially prepared canvas band, each by a drop of glue. The band was then suspended from the drum of an automatic exposure apparatus of special design.[1] In this way the words were exposed one at a time at a window in the front of the apparatus for a period of five seconds (Plate 5). The shift from one word to the next was practically instantaneous, though during the exposure, the word was stationary. The subject was directed to speak each word as quickly as possible after it appeared.

The reaction-time was measured by a John Hopkins chronoscope controlled by a tuning fork of special construction. The rate of this fork was calibrated against a Jaquet chronograph. It was such that the units of the chronoscope readings were .0034 of a second or approximately 1/300th. The chronoscope was connected electrically with the exposure apparatus in such a way that the

[1] For an account of this apparatus see Hull, C. L., Quantitative Aspects of the Evolution of Concepts, pp. 11-12 and 72. This study appears as No. 123 of the Psychological Review Monograph, 1920.

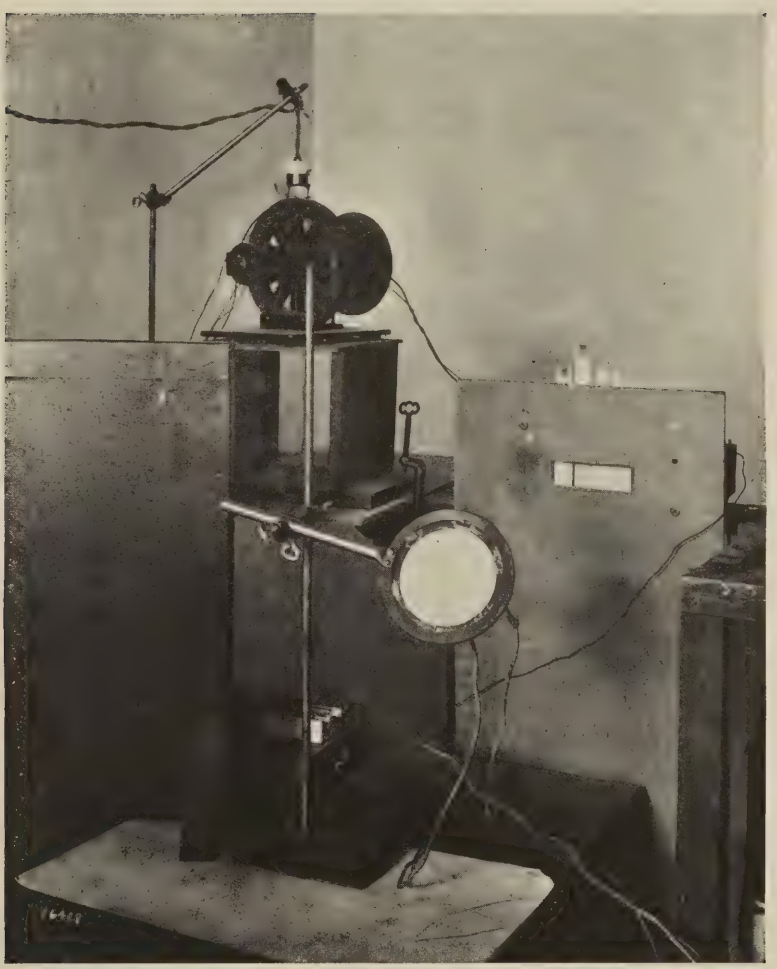

PLATE 5. Apparatus used for reaction-time and rote memory. Note the character showing at one of the windows of the memory apparatus. The apparatus itself is concealed by a special screen to avoid distraction of the subject's attention.

instant a word came into view, the timing part of the chronoscope was automatically set going. When the subject spoke the word, a sensitive voice key automatically stopped it. The reading of the chronoscope which had been taken before the word appeared, when subtracted from the reading taken after the response was given, yielded the time required for the reading of the word.

The voice key used was patterned after one designed by Dunlap.[2] It was supported by a standard in such a position that it was about an inch in front of the subject's lips as he sat in his natural position before the exposure apparatus looking at the word. The ordinary vibrations of the subject's voice were sufficient to set the delicate aluminum diaphram vibrating. This interrupted an electric circuit which instantly stopped the timing part of the chronoscope. Even with such a sensitive key there is always a certain, though small, amount of latency. But since this latency is the same in amount for the control days and the smoke days alike, it is automatically eliminated from the final results by our control technique, and its exact amount does not concern us.

In order that no avoidable variability be introduced into the experimental results, the same 30 words were used throughout the experiment. But lest the subjects should gradually learn the order of the words and thus materially change the nature of the test, 36 different bands were prepared on each of which the words were in a different chance order. Thus on each experimental day two different bands were used, each being used twice. Lest a constant error be introduced into the second and fourth tests of each day as a result of a familiarity of the order of the words already seen on the first and third tests, the second and fourth trials were always begun at widely different places on the band from the first. As a matter of fact the method of control used would have eliminated any such error from the final results had it existed. That no such tendency did result is shown very well by the fact that on the control days the second test of each experimental day averages a little

[2] This key consisted essentially of a stretched diaphram of aluminum foil 3.5 inches in diameter and .001 inch in thickness. In the middle of this on the back is a very light platinum disk which is just touched by a platinum point with fine screw adjustment.

slower in the case of both groups of subjects than the first (see Fig. 8).

The complete results of the typical subject on reading reaction-time are shown in Table XXII. The construction of this table and the various computations are as described above p. 39 ff. He shows

TABLE XXII

Reading reaction-time, subject No. 15, habitual smoker. Score, the time required to read a 4-letter word from an average of thirty, in units of .0034 sec.

	Original scores				Difference between normal of day and subsequent tests			
	Test	Test	Test	Test	Test	Test	Test	Average
Control	I	II	III	IV	II	III	IV	Difference
days:	(Normal)							
Nov. 8	172.3	170.4	178.2	177.4	+ 1.9	— 5.9	— 5.1	— 3.03
" 10	169.5	179.5	182.5	179.3	—10.0	—13.0	— 9.8	—10.93
" 11	166.4	171.6	174.5	168.4	— 5.2	— 8.1	— 2.0	— 5.10
" 13	164.3	171.1	170.8	169.4	— 6.8	— 6.5	— 5.1	— 6.13
" 16	161.0	168.1	169.8	171.5	— 7.1	— 8.8	—10.5	— 8.80
" 18	170.0	171.6	175.4	201.4	— 1.6	— 5.4	—31.4	—12.80
" 19	194.7	162.9	170.2	162.7	+31.8	+24.5	+32.0	+29.43
" 22	158.1	161.4	164.0	170.9	— 3.3	— 5.9	—12.8	— 7.33
Total	1356.3	1356.6	1385.4	1401.0	— .3	—29.1	—44.7	—24.69
Average	169.53	169.57	173.17	175.12	**— .04**	**— 3.63**	**— 5.59**	**— 3.08**
M. V.					8.44	7.04	10.54	8.15
P. E_M					2.52	2.10	3.15	2.43
Tobacco days:								
Nov. 7	172.7	181.5	182.7	179.6	— 8.8	—10.0	— 6.9	— 8.56
" 9	166.5	170.1	173.0	174.8	— 3.6	— 6.5	— 8.3	— 6.13
" 12	159.6	167.9	170.3	167.4	— 8.3	—10.7	— 7.8	— 8.93
" 14	156.6	161.8	177.6	166.3	— 5.2	—21.0	— 9.7	—11.96
" 15	173.9	165.3	176.1	176.8	+ 8.6	— 2.2	— 2.9	+ 1.16
" 17	167.2	163.9	165.3	159.0	+ 3.3	+ 1.9	+ 8.2	+ 4.46
" 20	169.1	159.4	169.3	148.6	+ 9.7	— .2	+20.5	+10.00
" 21	159.7	162.0	158.5	161.5	— 2.3	+ 1.2	— 1.8	— .96
" 23	—	—	—	—	—	—	—	—
Total	1325.3	1331.9	1372.8	1334.0	— 6.6	—47.5	— 8.7	—20.92
Average	165.66	166.49	171.60	166.75	**— .82**	**— 5.93**	**— 1.09**	**— 2.61**
M. V.					6.02	6.11	7.71	6.28
P. E_M					1.80	1.84	2.3	1.88
Effect of Tobacco:								
Difference					**— .78**	**— 2.30**	**+ 4.5**	**+ .47**
P. E_D					3.00	2.79	3.9	3.07
Ratio					.26	.82	1.15	.153
Reliability					.567	.705	.781	.54
Per cent gain or loss					**— .46**	**— 1.37**	**+ 2.68**	**+ .28**

Table XXIII

Effect of Tobacco on Reading Reaction-time, Non-smokers

Score, average time required to read a four letter work in units of .0034 seconds. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 18.5 min.				Effect, second post-dosage test (after 53.5 min.)				Effect, third post-dosage test (after 1 hr. 28.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
1	— 8.84	4.28	.917	—5.80	— 4.64	4.06	.779	—3.04	— 8.01	2.18	.999	—5.30
2	+ 7.50	3.22	.941	+4.40	+ 3.90	4.49	.721	+2.20	+ 4.20	4.11	.754	+2.40
3	+ 8.30	2.85	.975	+3.80	+ 5.80	3.71	.854	+2.70	+ 8.30	4.70	.883	+3.80
4	+ 1.40	1.63	.719	+ .80	+ .10	1.61	.516	+ .05	+ 4.40	2.06	.924	+2.50
5	— 5.90	4.24	.825	—2.90	— 4.00	4.58	.721	—1.90	— 3.34	4.61	.686	—1.60
6	+16.60	3.66	.998	+7.80	+ 6.80	3.77	.889	+3.20	+ 8.40	3.69	.937	+3.90
7	+ 8.21	3.80	.927	+4.32	+ 6.10	3.09	.907	+3.21	+ 6.20	3.44	.889	+3.26
8	— 1.20	2.68	.618	— .70	— 1.82	2.56	.684	—1.07	+ .05	3.29	.504	+ .03
9	— 8.13	3.68	.932	—4.93	—11.43	5.88	.905	—6.93	+11.19	5.21	.926	—6.79
Average	+ **1.99**	3.34		+ **.754**	+ **.09**	3.75		— **.175**	+ **1.00**	3.70		+ **.244**
M. V.	7.252			3.855	4.944			2.719	5.887			3.252
P. E.$_M$ (A)	2.050			1.090	1.393			.766	1.659			.916
Reliability (A)	**.739**			.670	**.514**			.560	**.657**			.567
P. E.$_M$ (B)	1.110				1.250				1.230			
Reliability (B)	.890				.520				.705			

TABLE XXIV

EFFECT OF TOBACCO ON READING REACTION-TIME, HABITUAL SMOKERS

Score, average time required to read a four letter word in units of .0034 seconds. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 18.5 min.)				Effect, second post-dosage test (after 53.5 min.)				Effect, third post-dosage test (after 1 hr. 28.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	[1]											
11	—4.10	1.50	.967	—2.40	—4.60	2.20	.931	—2.70	—4.40	1.25	.991	—2.60
12	[1]											
13	+9.08	6.04	.844	+4.08	+8.32	5.45	.848	+3.74	+5.67	7.38	.698	+2.55
15	— .78	3.00	.567	— .46	—2.30	2.79	.705	—1.37	+4.50	3.90	.781	+2.68
16	+9.30	4.01	.942	+4.42	—2.40	5.14	.619	—1.14	+9.30	4.82	.903	+4.42
17	—1.41	2.84	.630	— .78	—1.58	2.31	.677	— .87	—4.38	2.77	.857	—2.42
18	+3.94	2.00	.908	+1.99	—1.70	2.15	.703	— .86	+ .50	2.11	.562	+ .25
19	+ .13	2.05	.516	+ .08	+5.00	1.39	.992	+2.74	+ .20	1.69	.530	+ .10
Average	**+2.31**	3.11		**+ .99**	**+ .11**	3.06		**— .06**	**+1.63**	3.42		**+ .71**
M. V.	4.40			2.15	3.74			1.89	4.17			2.15
$P.E._{M}$ (A)	1.41			.69	1.19			.60	1.31			.69
Reliability (A)	**8.67**			.836	**.521**			.527	**.80**			.760
$P.E._{M}$ (B)	1.180				1.160				1.290			
Reliability (B)	.906				.527				.801			

[1] The chronoscope was not available for use with subjects 10 and 12.

no reliable effect of smoking, though his final average takes the form of a minute gain in speed.

The final results of the non-smokers and the habitual smokers are shown in Tables XXIII and XXIV respectively. A glance at the signs in the body of these tables reveals a striking lack of agreement among the various subjects as to the effect of the tobacco, though in both tables there will be found a slight majority of plus signs. The final averages of both groups agree also in showing a slight stimulation as the result of smoking, though none

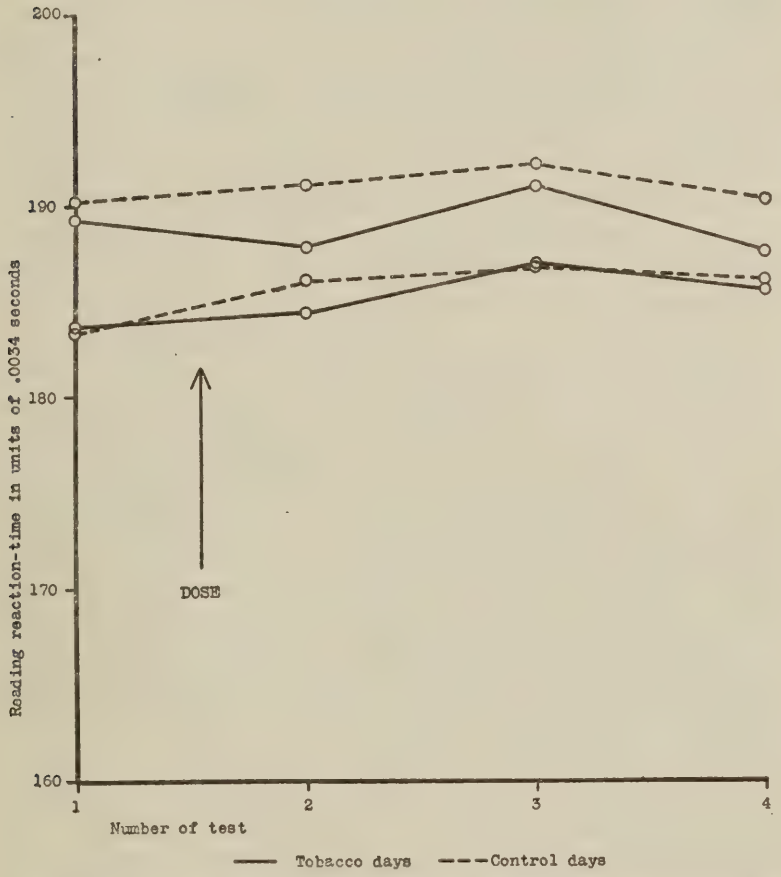

FIG. 8. The effect of smoking on the speed of reading four-letter words. Two upper curves, habitual smokers; two lower curves, non-smokers.

of the average differences approach even remotely to a satisfactory statistical reliability.

The average course of the reaction-time throughout the experimental day was also computed for both groups of subjects separately and for both the tobacco and the control days. The group of habitual smokers turns out, on the average, somewhat less efficient (i.e., slower) than the non-smokers. While the statistical reliability of this difference shows that it has no significance as to any permanent effects of tobacco, it is large enough to permit the control and drug curves of both groups of subjects to be shown in the same figure without interference. They appear in Fig. 8. A careful examination of these two sets of curves reveals a striking similarity between them. In each there is a marked separation of the drug from the control curve at the first post-dosage test. This is followed in each case by an approach of the two curves on the second post-dosage test, only to be succeeded on the last test by a divergence as great as the first. Despite the low statistical reliability of these differences, the marked agreement of the two sets of results, particularly when taken in connection with other results of strikingly similar nature to be met with in subsequent chapters, furnishes some grounds for the belief that the peculiarities in the results noted above, may indicate a real tendency. This would mean that under conditions of the present experiment, smoking may produce a certain immediate effect, which later subsides, only to recur once more with an intensity more or less approaching that of the original effect. This hypothesis will be referred to from time to time as other evidence is encountered. An attempt at a possible explanation will be made in the final chapter of the monograph.

The final summary and evaluation of the results of the present investigation will be reserved until the end of the following chapter.

CHAPTER X

The Effect of Smoking on the Speed of Oral Reaction to Freshly Learned Material

In the last chapter we considered the effect of smoking on the rapidity of the functioning of thoroughly formed ocular-vocal associative bonds of long standing. In the present chapter we shall consider the effect of smoking on the rapidity of the functioning of ocular-vocal associative bonds which have just been established and which in strength are only just above the threshold of recall. The associative bonds in question were those formed in connection with the learning test described in Chapter XIV. For this reason the description of the technique of the present experiment necessarily anticipates more or less what will be described in more detail there. The material consisted of fairly simple meaningless geometrical characters and nonsense syllables. Examples of the characters used are shown in Plate 6. One syllable was associated with one character by a prompting method in such a way that whenever the character appeared at the window of the exposure apparatus, the syllable would be spoken into the voice key by the subject. Psychologically, the test was very much like reading words of a foreign language without knowing their meaning.

Only five of the characters and as many syllables were used on a given test. Six exact photographic duplicates of each character were provided. The photographs were cut up in such a way that each character was in the middle of a card about ¾-inch square. These were attached to a canvas band, each with a drop of glue exactly as were the printed words in the test described in the last chapter. By means of the photographic duplicates the 5 characters were placed on the band in 6 different random orders, making 30 entries in all. In the experiment, this band made two complete revolutions before the window of the exposure apparatus, instead of one as with the 30 words. Ordinarily the first revolution sufficed to establish the associative bonds between the characters and

their respective assigned phonetic values, well enough so that thereafter when the subject would see a character at the window he could respond with the syllable without error. This left the second revolution of the band free for giving the reaction-times from this freshly learned material. During this second revolution, the apparatus and technique were exactly the same as described in Chapter IX for the 30 words. The reaction-times thus obtained constitute the data of the present investigation.

A number of imperfections in the above method may now be mentioned. The first one lies in the well known fact that the speed of reaction at any given time, depends to a great extent upon the strength of the associative bond involved. Clearly, then, if the tobacco should have a retarding effect upon the learning, say, the associative bonds during the second revolution of the band would be weaker than on the control days. This in itself would retard the reaction-time on the tobacco days entirely apart from any effect of the tobacco upon the speed of functioning of this kind of associative bond as such. It is interesting to note, however, that the case where the most striking average effect of tobacco appears on the two processes under consideration, they are in exactly opposite directions. This suggests that the tendency noted above may have been so slight as to be negligible.

A much more serious defect lies in the fact that some subjects learned so slowly that the promptings had to be extended far into the second revolution of the band. This reduced the number of reaction-times which could be obtained from certain subjects so greatly that their results had to be thrown out entirely. In the results of several others which are included in the final tables, tests now and then had to be thrown out for the same reason and in case the test chanced to be the first one of the day, the results of the entire day had to be discarded. And of the records actually used, many have less than the full 30 reaction-times for the same reason. Last of all may be mentioned occasional apparatus trouble. But it must be admitted that the general consistency of the final average results of this investigation is somewhat surprising in view of the irregularities just enumerated. Great care, however, was exercised in the scoring of the results, such as they were, and

it is possible that the technique was really more reliable than it appears on the surface.

The results of the typical subject are shown in detail in Table XXV. It will be noted that the scores for November 7 and 23 were

TABLE XXV

Learning reaction-time, subject No. 15, habitual smoker. Score, average reaction-time on last 30 presentations of characters in learning test, in units of .0034 sec.

	Original scores				Difference between normal of day and subsequent tests			
	Test	Test	Test	Test	Test	Test	Test	Average
Control	I	II	III	IV	II	III	IV	Difference
days:	(Normal)							
Nov. 8	254.3	287.1	324.9	281.6	—32.8	—70.6	—27.3	—43.56
" 10	239.4	315.9	291.4	236.1	—76.5	—52.00	+ 3.3	—41.73
" 11	320.7	257.5	250.9	244.4	+63.2	+69.8	+76.3	+69.76
" 13	277.2	285.0	246.5	277.4	— 7.8	+30.7	— .2	+ 7.56
" 16	253.3	248.3	269.6	217.4	+15.0	— 6.3	+45.9	+18.20
" 18	249.6	244.8	258.3	267.3	+ 4.8	— 8.7	—17.7	— 7.20
" 19	250.4	219.3	271.7	253.7	+31.1	—21.3	— 3.3	+ 2.16
" 22	283.4	255.1	264.2	293.6	+28.3	+19.2	—10.2	+12.43
Total	2138.3	2113.0	2177.5	2071.5	+25.3	—39.2	+66.8	+17.62
Average	267.29	264.12	272.19	258.93	+ **3.16**	— **4.9**	+ **8.35**	+ **2.20**
M. V.					31.65	33.6	26.37	24.78
P. E_M					9.47	10.03	7.88	7.41
Tobacco days:								
Nov. 7	—	—	—	—	—	—	—	—
" 9	270.2	295.1	283.0	265.3	—24.9	—12.8	+ 4.9	—10.93
" 12	313.0	288.8	266.7	222.1	+24.2	+46.3	+90.9	+53.80
" 14	222.3	214.8	272.1	307.3	+ 7.5	—49.8	—85.0	—42.43
" 15	229.4	286.2	206.7	210.7	—56.8	+22.7	+18.7	— 5.13
" 17	289.4	288.9	270.9	245.9	+ .6	+18.6	+43.6	+20.93
" 20	233.2	199.0	218.9	244.9	+34.2	+14.3	—11.7	+12.26
" 21	250.9	216.2	194.4	250.9	+34.7	+56.5	0	+30.40
" 23	—	—	—	—	—	—	—	—
Total	1808.5	1789.0	1712.7	1747.1	+19.5	+95.8	+61.4	+58.9
Average	258.35	255.57	244.67	249.59	+ **2.78**	+**13.68**	+ **8.77**	+ **8.41**
M. V.					25.56	25.79	36.25	23.92
P. E_M					8.16	8.23	11.57	7.62
Effect of Tobacco:								
Difference					— **.38**	+**18.58**	+ **.42**	+ **6.21**
P. E_D					12.49	12.96	14.00	10.63
Ratio					.03	1.43	.03	.584
Reliability					.5135	.836	.5135	.657
Per cent gain or loss					— **.14**	+ **7.07**	+ **.16**	+ **2.36**

so defective that they were thrown out. The construction of this table and the various computations are exactly as described on pp. 39 ff. and 49 ff. His final average, while somewhat erratic, shows in general a tendency to an increase in efficiency (speed) as the result of smoking, though the differences in no case approach a satisfactory statistical reliability.

The final results of the influence of smoking on the speed of functioning of newly formed associative bonds, are shown for the non-smokers and the habitual smokers in Tables XXVI and XXVII respectively. An inspection of the signs in the body of these tables reveals a striking lack of agreement among the various subjects as to the effect of tobacco, exactly as was found in the investigation of reading reaction-time. And also as with the reading, there is a slight preponderance of plus signs with both groups of subjects. The present results resemble those on reading-time also in that the final averages with both groups of subjects show a slight gain in speed of reaction as the result of smoking, though again this in no case attains a satisfactory statistical reliability. As a last point of resemblance, it must be pointed out that with both groups of subjects we find here also, on the second post-dosage test, the curious disappearance of the original effect with its subsequent recurrence with original strength on the last test as noted on p. 94.

With a view to getting further light on certain points, the average course of the learning reaction-time throughout the experimental day was computed for both groups of subjects and for both the tobacco and the control days. These data are shown as parallel curves in Figures 9 and 10 for the non-smokers and the habitual smokers, respectively. As pointed out above, the reaction-time for weak associative bonds are much slower than for strong. The time required with the present material was about 50 per cent greater than that for reading the four-letter words. The present results have therefore been plotted to a correspondingly smaller scale so as to facilitate comparison. The curves of Figures 9 and 10 show perhaps a little greater irregularity than those of Fig. 8 which is to be expected from the irregularities in the present data already described. The usual slowness of the habitual smokers as compared

TABLE XXVI

EFFECT OF TOBACCO ON SPEED OF REACTION-TIME TO FRESHLY LEARNED MATERIAL, NON-SMOKERS

Score, average reaction-time in units of .0034 seconds at the last 30 presentations of characters in learning test. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 25. min.)				Effect, second post-dosage test (after 60 min.)				Effect, third post-dosage test (after 1 hr. 35 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
1	—11.70	9.83	.789	— 4.28	— 7.60	14.37	.636	—2.78	—15.24	12.32	.796	— 5.58
2	[1]											
3	— 9.30	24.80	.599	— 2.30	— 7.10	14.70	.627	—1.80	+ .40	22.70	.505	+ .10
4	+43.50	22.49	.903	+14.50	+20.80	32.33	.667	+6.90	+52.20	29.58	.882	+17.40
5	[2]											
6	+40.87	19.55	.920	+12.20	— 6.95	18.25	.601	—2.07	+16.73	18.44	.743	+ 5.00
7	+18.42	19.25	.739	+ 5.66	+22.17	19.34	.779	+6.82	+31.36	8.31	.995	+ 9.64
8	— 3.22	8.03	.506	— 1.55	— 9.60	7.41	.807	—4.64	+10.56	11.88	.724	+ 5.11
9	+13.05	12.27	.763	+ 5.39	— 2.60	14.35	.548	—1.07	—20.10	10.30	.906	— 8.30
Average	**+13.09**	16.60		**+ 4.231**	**+ 1.30**	17.25		**+ .19**	**+10.84**	16.22		**+ 3.34**
M. V.	18.16			5.95	11.53			3.81	19.36			6.90
$P.E._{M}$ (A)	5.79			1.897	3.68			1.214	6.184			2.203
Reliability (A)	**.936**			.931	**.593**			.540	**.881**			.844
$P.E._{M}$ (B)	6.260				6.510				6.130			
Reliability (B)	.921				.553				.881			

[1] This subject's reactions in this test were so defective that the results were of no value.

[2] This subject's learning was so slow that there were not enough successful reactions at the end of the 60 trials to give a measure of his reaction-time.

TABLE XXVII

EFFECT OF TOBACCO ON SPEED OF REACTION-TIME TO FRESHLY LEARNED MATERIAL, HABITUAL SMOKERS

Score, average reaction-time in units of .0034 seconds at the last 30 presentations of characters in learning test. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 25 min.)				Effect, second post-dosage test (after 60 min.)				Effect, third post-dosage test (after 1 hr. 35 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	[1]											
11	[2]											
12	[1]											
13	+ 6.65	17.17	.604	+ 1.50	— 2.70	18.28	.540	— .60	+53.11	28.07	.899	+11.90
15	— .38	12.49	.514	— .14	+18.58	12.96	.836	+ 7.07	+ .42	14.00	.513	+ .16
16	+42.90	57.69	.692	+15.85	+34.10	45.22	.694	+12.60	+46.00	64.56	.684	+17.00
17	—24.37	7.83	.982	— 8.18	—52.57	18.81	.970	—17.65	—23.10	13.76	.870	— 7.76
18	[2]											
19	—13.68	8.62	.857	— 4.60	+ 8.27	13.87	.655	+ 2.78	+11.08	17.25	.667	+ 3.80
Average	**+ 2.22**	20.76		**+ .89**	**+ 1.13**	21.83		**+ .84**	**+17.50**	27.53		**+ 5.02**
M. V.	18.04			6.23	23.02			7.97	25.65			7.54
P. $E._{M}$ (A)	6.82			2.35	8.70			3.01	9.70			2.85
Reliability (A)	**.580**			.606	**.540**			.567	**.89**			.881
P. $E._{M}$ (B)	9.280				9.760				12.310			
Reliability (B)	.567				.527				.828			

[1] The chronoscope was not available for use with these two subjectts.

[2] The learning of these subjects was so slow that reliable reaction-time could not be secured.

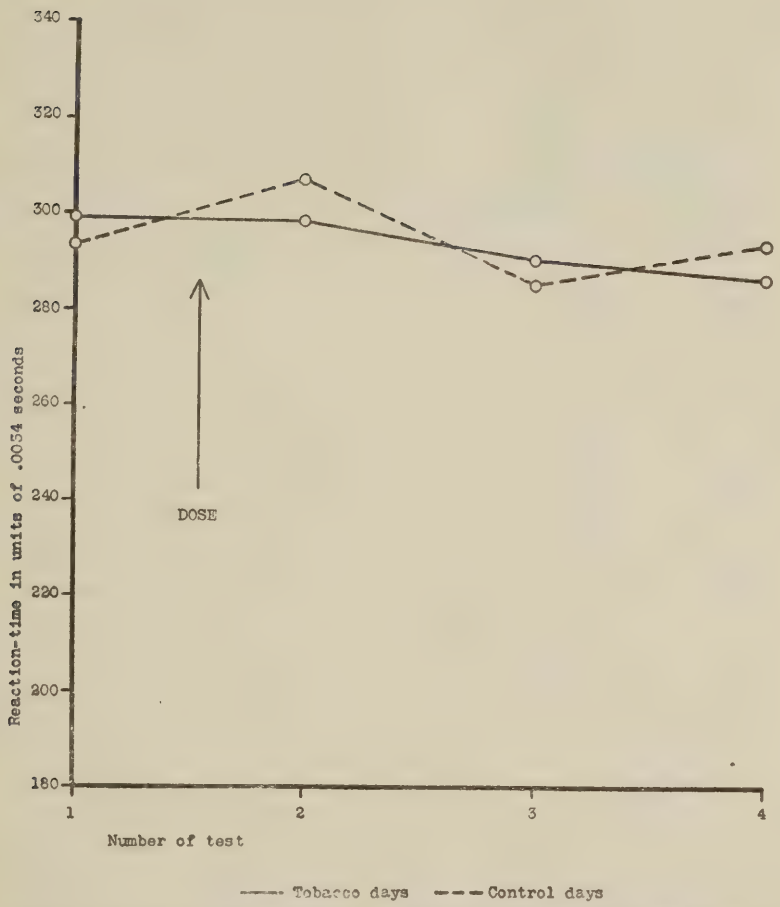

FIG. 9. The effect of smoking on the speed of reacting to freshly learned material, non-smokers.

with the non-smoking group appears, but it has no significance as to any permanent effect of tobacco. Lastly a careful comparison of the present curves with each others and with those of Fig. 8 will show once more the peculiar rhythmical effect noticed in Chapter IX, to be common to all four pairs of curves.

The present writer has been unable to find in the literature any experimental results as to the influence of smoking on reaction-time, though it is understood that an intensive investigation of this subject has been under way for some time. Accordingly our

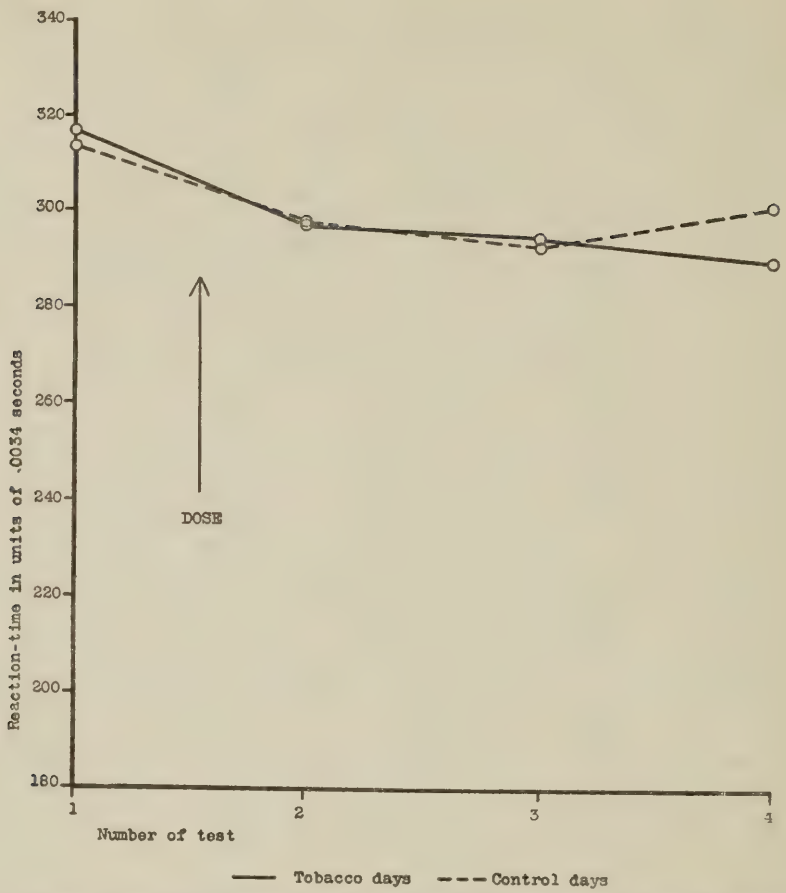

FIG. 10. The effect of smoking on the speed of reacting to freshly learned material, habitual smokers.

conclusions must be based entirely upon the results of the two investigations here reported. They may be summarized as follows:

1. The final averages from neither of the groups of subjects and from neither of the two tests yield a single effect of any kind which attains a satisfactory statistical reliability.

2. It is noteworthy, however, that the final averages in all four cases agree in showing a small average gain in efficiency (speed) as the result of smoking—around 1%. This striking agreement under the variety of conditions lends to the four averages taken

together, a reliability considerably greater than that shown in the tables where they stand alone. Roughly speaking, the probable error of all four sets of data taken together is only about half that for any one set alone. Under this assumption, the chances are around 15 to 1 that smoking causes a very slight stimulating effect on the speed of functioning of ocular-vocal associative bonds on the first and last post-dosage tests.

CHAPTER XI

The Effect of Smoking on the Speed of Continuous Mental Addition

In Chapter IX we considered the effect of smoking on the speed of the functioning of thoroughly formed associative bonds of a sensory-motor type. It will be observed that the physical element in that process is still fairly large. In the present chapter, we shall pass to the consideration of the effect of smoking upon the rapidity of the functioning of thoroughly formed associative bonds which are on the strictly mental level. The form of the addition test employed was an adaptation of one described by Starch.[1] It is so completely "mental" that it does not require even the writing down of answers by the subject. No apparatus is required. The subject takes up any comfortable position that he prefers. The experimenter says "Ready," starts his stop-watch and at the same time calls out a two-place number such as 26. The subject then proceeds to add to this the digit 6, to that total 7, to that total 8, then 6, then 7, then 8 and so on continuously as rapidly and accurately as possible, calling out the totals (only) as they are obtained. Thus the first few totals starting as indicated above would be: (26) 32, 39, 47, 53, 60, 68, 74, and so on. When 100 is reached, the hundreds are dropped from the totals, the subject never speaking more than the first 2 digits. At the end of 30 seconds the experimenter interrupts the subject by speaking a new number—say 84. The subject immediately begins adding to this number the 6, 7, and 8 as before and continues for 30 seconds, when a new number is given, and so on. The adding is continued for 5 minutes at each test and yields 10 sets of additions.

For recording the performance in this test, special mimeographed sheets were prepared containing in parallel columns the totals for the various starting numbers as far as 25 additions each. The experimenter would call out the number at the top of the

[1] Starch, D., Experiments in Educational Psychology, p. 172 ff.

column and then follow along down the series of totals with his pencil as the subject spoke them until 30 seconds had elapsed, when he would draw a line beneath the last total given, at the same time calling out the number at the top of the next column. In case the subject made an error part may down the column as often

TABLE XXVIII

Adding, subject No. 15, habitual smoker. Score number of correct additions performed in five minutes.

	Original scores				Difference between normal of day and subsequent tests			
	Test	Test	Test	Test	Test	Test	Test	Average
Control	I	II	III	IV	II	III	IV	Difference
days:	(Normal)							
Nov. 8	123	144	132	128	+21	+ 9	+ 5	+11.66
" 10	155	153	136	166	— 2	—19	+11	— 3.33
" 11	149	147	153	154	— 2	+ 4	+ 5	+ 2.33
" 13	157	153	156	154	— 4	— 1	— 3	— 2.66
" 16	187	178	185	182	— 9	— 2	— 5	— 5.33
" 18	198	206	183	201	+ 8	—15	+ 3	— 1.33
" 19	212	219	206	212	+ 7	— 6	0	+ .33
" 22	228	239	207	225	+11	—21	— 3	— 4.33
Total	1409	1439	1358	1422	+30	—51	+13	— 2.66
Average	176.12	179.87	169.75	177.75	+ 3.75	— 6.37	+ 1.62	— .33
M. V.					8	8.97	4.25	3.83
P. E_M					2.39	2.68	1.27	1.14
Tobacco days:								
Nov. 7	103	110	125	118	+ 7	+22	+15	+14.66
" 9	165	140	148	158	—25	—17	— 7	—16.33
" 12	179	173	182	181	— 6	+ 3	+ 2	— .33
" 14	172	198	192	190	+26	+20	+18	+21.33
" 15	192	194	190	200	+ 2	— 2	+ 8	+ 2.66
" 17	197	218	205	200	+21	+ 8	+ 3	+10.66
" 20	236	226	221	209	—10	—15	—27	—17.33
" 21	206	224	229	217	+18	+23	+11	+17.33
" 23	222	236	227	241	+14	+ 5	+19	+12.66
Total	1672	1719	1719	1714	+47	+47	+42	+45.33
Average	185.77	191	191	190.44	+ 5.22	+ 5.22	+ 4.66	+ 5.03
M. V.					13.30	11.60	10.60	11.40
P. E_M					3.75	3.27	2.99	3.21
Effect of Tobacco:								
Difference					+ 1.47	+11.59	+ 3.04	+ 5.36
P. E_D					4.45	4.23	3.25	3.41
Ratio					.33	2.74	.94	1.57
Reliability					.593	.968	.739	.859
Per cent gain or loss					+ .81	+ 6.40	+ 1.68	+ 2.96

happened, the experimenter recorded the incorrect total on the sheet by the side of the corresponding correct one and beneath this in a column all the following totals given during the remainder of the half minute. This was necessary because, once an error is made, all the remaining totals will differ from the printed series even though all the subsequent additions be correct. Occasionally very rapid adders succeeded in making more than the 25 additions in the allotted 30 seconds, in which case the additional totals given were recorded beneath the appropriate column. The score in this test is the total number of correct additions performed in the 5 minutes. The score on errors will be considered in detail in Chapter XII.

The results of the typical subject on speed of adding are shown in detail in Table XXVIII. The construction of this table and the various computations are exactly as described on pages 39 ff. and 49 ff. This subject shows a fairly consistent increase in the rate of addition as the result of smoking. One of the differences attains a satisfactory statistical reliability.

The final results with the present test reveal perhaps the most interesting and important effects of smoking found in the entire investigation. The final averages are shown in Tables XXIX and XXX for the non-smokers and the habitual smokers respectively. An inspection of the results with the non-smokers shows, with a single exception, a consistent loss in efficiency (speed) as the result of smoking. The habitual smokers, on the other hand, show a uniform *gain* in efficiency with no exception whatever. The statistical reliabilities of all averages with both groups of subjects are practically perfect. Despite these high reliabilities, however, the effects themselves are not excessive. The loss in efficiency among the non-smokers averages —2.77 per cent for the post-dosage period, while the gain among the habitual smokers averages +5.21. It is also important to note that the bad effect on the non-smokers shows no signs of subsiding at the close of the experimental day (approximately 1 hour and 15 minutes after the dose) and the stimulating effect on the habitual smokers seems to be slightly increasing.

In order to secure further light on the above results, the average

TABLE XXIX

EFFECT OF TOBACCO ON SPEED OF ADDITION, NON-SMOKERS

Score, number of correct additions performed in 5 minutes. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 4.5 min.)				Effect, second post-dosage test (after 39.5 min.)				Effect, third post-dosage test (after 1 hr. 14.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
1	— 4.40	3.71	.787	— 1.70	+ 2.20	6.78	.586	+ .84	— 2.00	5.43	.596	— .77
2	—25.80	7.12	.992	—11.20	—13.80	9.77	.829	—6.00	—12.00	5.19	.940	—5.20
3	+ 4.80	2.68	.887	+ 5.10	+ 1.10	3.82	.575	+1.20	+ 3.30	2.71	.792	+3.50
4	— 7.40	4.58	.861	— 2.30	—14.20	8.05	.882	—4.50	—10.87	7.52	.833	—3.40
5	— 4.00	6.27	.664	— 1.70	+ 1.30	6.47	.554	+ .59	— 5.70	5.46	.758	—2.50
6	— 8.70	8.30	.760	— 2.50	— 8.30	6.92	.790	—2.40	—10.80	9.71	.773	—3.10
7	— 7.96	2.94	.965	— 3.50	—14.50	4.17	.990	—6.40	—12.00	4.25	.971	—5.30
8	— 6.30	4.50	.827	— 3.20	—11.90	4.80	.952	—6.15	—11.80	5.40	.929	—6.10
9	— 3.54	5.40	.669	— 1.32	—15.53	6.16	.955	—5.80	— 1.63	5.56	.577	— .61
Average	**— 7.03**	5.06		**— 2.48**	**— 8.18**	6.33		**—3.18**	**— 7.06**	5.69		**—2.61**
M. V.	4.82			2.328	6.476			2.879	4.90			2.234
$P. E._M$ (A)	1.358			.656	1.825			.811	1.381			.629
Reliability (A)	**1.000**			.994	**.998**			.996	**1.000**			.997
$P. E._M$ (B)	1.685				2.112				1.897			
Reliability (B)	.997				.995				.994			

TABLE XXX

EFFECT OF TOBACCO ON SPEED OF ADDITION, HABITUAL SMOKERS

Score, number of correct additions performed in 5 minutes. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 4.5 min.)				Effect, second post-dosage test (after 39.5 min.)				Effect, third post-dosage test (after 1 hr. 14.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	+ 8.40	4.56	.893	+ 5.48	+ 8.00	6.38	.800	+5.22	+17.00	7.09	.947	+11.09
11	+ 5.50	8.06	.681	+ 1.80	+11.00	8.00	.827	+3.60	+13.96	9.55	.836	+ 4.60
12	+ 5.06	5.33	.739	+ 1.90	— 3.43	6.23	.645	—1.30	+13.07	6.52	.911	+ 5.10
13	+ 7.72	4.20	.893	+ 7.07	+ 6.63	3.88	.876	+6.07	+14.20	4.93	.974	+13.00
15	+ 1.47	4.45	.593	+ .81	+11.59	4.23	.968	+6.40	+ 3.04	3.25	.739	+ 1.68
16	+ 8.90	4.88	.892	+ 3.78	+14.10	5.07	.969	+6.00	+10.50	3.05	.990	+ 4.51
17	+ 2.55	3.55	.686	+ 1.06	+10.55	4.77	.932	+4.39	+20.05	4.15	.999	+ 8.36
18	— 5.92	4.28	.824	— 3.37	+ 9.00	5.10	.883	+5.13	+ 9.72	4.35	.935	+ 5.55
19	+21.12	4.58	.999	+12.74	+16.13	5.31	.980	+9.73	+17.88	3.79	.999	+10.78
Average	+ **6.09**	4.88		+ **3.47**	+ **9.29**	5.44		+ **5.03**	+**13.26**	5.19		+ **7.19**
M. V.	4.84			3.37	3.76			1.86	3.72			3.22
$P.E._M$ (A)	+ 1.36			.95	1.06			.52	1.05			.91
Reliability (A)	**.999**			.993	**1.00**			1.00	**1.00**			1.00
$P.E._M$ (B)	1.63				1.81				1.73			
Reliability (B)	.994				1.00				1.00			

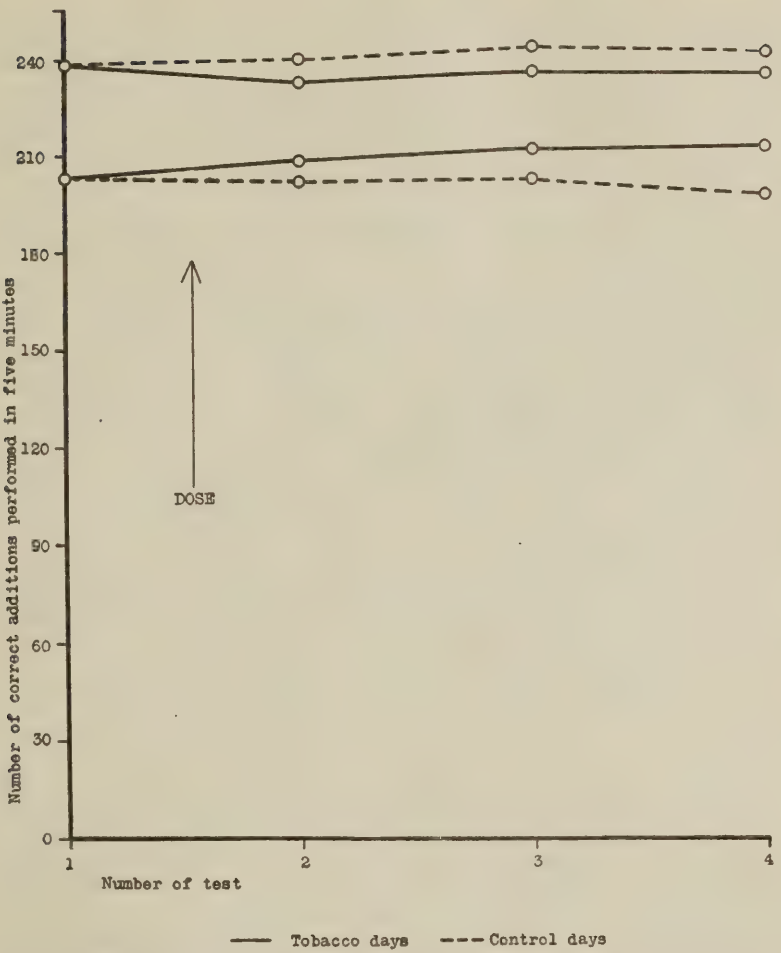

FIG. 11. The effect of smoking on the rate of adding. Two upper curves, non-smokers; two lower curves, habitual smokers.

course of the rate of adding throughout the experimental day was computed for both the smokers and the non-smokers, and for the drug and control days separately. The results for both groups of subjects are shown in parallel in Fig. 11. As usual we find the habitual smokers, on the average, somewhat less efficient than the non-smokers. The difference in this case amounts to about 17 per cent. Its reliability is only .890 however, so that it has no particular

significance. Turning our attention to the respective pairs of curves, we find them showing excellent consistency. The drug and control curves in each case originate from practically the same point. Thereafter there is a distinct separation, opposite in direction in the two cases, which is maintained to the end of the experimental day.

The results of the present investigation my briefly be formulated as follows:

1. Among non-smokers, smoking causes a very consistent *loss* in rate of adding, averaging —2.77 per cent.

2. While not large, this loss in efficiency seems to be rather durable, since there are no signs of recovery 1 hour and 15 minutes after the termination of the smoking.

3. Among the habitual smokers, on the other hand, smoking causes with great regularity a *gain* in the rate of adding amounting, on the average to +5.21 per cent.

4. With the habitual smokers, also the effect seems to be unusually persistent, there being again no sign of a return to normal at the close of the experimental day.

5. Habituation seems, therefore, definitely and completely to have reversed the effect of the drug with respect to this particular test.

A number of different investigators have reported results bearing on the relation of smoking to the rate of adding. Before proceeding to the consideration of these results however it must be noted that the form of the adding test used in securing them differed in certain respects from that used in the present experiment. In all the previous investigations the subjects have added short columns of figures and recorded the totals themselves. In the present experiment, on the other hand, the numbers to be added were never seen by the subject at all but must instead be held in *mind* by him continuously in their recurring order as described above. These complexities added to the already complex mental processes of ordinary addition probably made the present method somewhat more exacting in its demands upon the attention of the adder. Even so, there appears to be rather good agreement between the

present results and those of previous investigations. Froeberg[2] in a fairly well controlled experiment, found 5 non-smokers averaging a loss in efficiency of —5.9 per cent. This agrees with the results of our own non-smokers though it it somewhat larger in amount. Berry,[3] on the other hand, found with himself (habitual smoker) a gain in efficiency of +6.3 per cent.[4] This is in substantial agreement with our results from habitual smokers. Johnson[5] also reports a small amount of evidence suggesting that smoking improves adding efficiency though he does not state the smoking habits of his subjects. Bush,[6] however, reports results in complete disagreement. He found with a group, chiefly habitual smokers, a loss in adding efficiency as the result of smoking of —9 per cent. Unfortunately, as pointed out above, the technique of Bush's experiment is open to such question that it is difficult to say how much weight should be attached to his results. The present writer is inclined to discount them rather heavily. Assuming this view to be sound, the indication of the available evidence as to the effect of smoking on adding efficiency is pretty clear. It decreases somewhat the efficiency of non-smokers but quite markedly increases that of the habitual smokers.

But before accepting the above formulation as final, we must give careful consideration to a fundamental question which has been latent wherever we have considered the results from habitual smokers—that of withdrawal or privation effects. That marked effects are produced in subjects who are accustomed to the use of certain habit-forming drugs when the usual dose is withheld for some time, is well known.[7] These effects are ordinarily in the direction of a loss in functional efficiency. The question therefore rises insistently at this point: Were the post-dosage scores on the drug days superior to those on the control days because of an inherently stimulating action of the tobacco on the drug days, or because of a depressing effect caused by the *lack* of the accustomed

[2] See p. 14 above.
[3] See p. 13 above.
[4] See Appendix F.
[5] See p. 13 above.
[6] See p. 12 above.
[7] Pettey, G. E., Narcotic Drug Diseases, pp. 13-14, also 304-305.

dose on the control days? The question is an extremely difficult one but it is so fundamental for the interpretation of the results of the habitual smokers that it must at least be faced squarely and in the light of whatever evidence is available. Fortunately the present investigation yields a considerable number of parallel records from the same set of habitual smokers in a variety of mental functions, as well as corresponding records from a group of non-smokers who, for the present purpose, may be considered as a kind of control squad.

The first question to be considered is the extent of withdrawal of the drug which actually took place on the control days. It will be recalled (Chapter II) that on these days the subjects received no tobacco during the experiment though the nature of the control dose was such that they were led to believe that they did. This fact served to eliminate any pseudo withdrawal effects which might have resulted from autosuggestion. Moreover, being keenly aware of the danger from withdrawal effects from the first, the writer planned the technique of the experiment with the express intention of eliminating them so far as possible. To this end the second squad of subjects was limited almost entirely to pipe rather than cigarette smokers because the former, while probably consuming as much tobacco in the aggregate, take it at considerably longer intervals. This fact made it possible without disturbing their regular smoking habits, to have them report to the laboratory without having smoked for at least 3 hours preceding arrival. Their habits, however, usually did call for a smoke at about the time the first test was given or a little before, it being shortly after a meal. Therefore the first test where any particular withdrawal effects might be expected would be the first post-dosage test. The duration of the withdrawal at this stage would be about an hour or a little more, while that for the last post-dosage test would be between 2½ and 3 hours.

The next question to be considered is whether, as a matter of fact, this amount of withdrawal actually did produce privation effects with the habitual smokers? For reasons given in the last paragraph it is assumed that the score on the pre-dosage test is free from any noticeable withdrawal effects. Then if any such effects exist, they

should manifest themselves either as a falling off of the score during the post-dosage period from the level set by the pre-dosage test or at least by a relative falling off as compared with the corresponding pre- and post-dosage scores of subjects clearly free from any such suspicion of withdrawal effects in the control scores of the non-smokers. And while it would perhaps be rash to say that the average course of performance in the various tests would be identical for these two groups of subjects except for possible withdrawal effects, a consistent difference between them in one direction or the other may quite properly constitute a presumption in favor of, or against the existence of such effects. As an example of the difference in question, the non-smokers on the control days showed an average slump on the post-dosage tests in reading reaction-time of about 3 points. The habitual smokers under similar conditions, also show a slump, but only 1 point. This gives the habitual smokers an advantage of about 2 points. There is thus no indication of a pernicious withdrawal effect here and the presumption is distinctly against it.

For the purpose of getting as comprehensive a view of this matter as possible, the results from the 7 tests in which reliable results are available from both groups of subjects have been assembled in Table XXXI. An inspection of the last two columns of this table shows that out of the 6 strictly mental tests, only one (adding) shows any tendency whatever in the direction of a pernicious withdrawal effect. If we include tapping, a strictly physical test which happens to show a loss, the average effect in the entire group of 7 tests is a gain of 4.35 per cent. There is thus quite clearly no *general* tendency to a loss in functional efficiency on the part of the habitual smokers as the result of failure to receive the accustomed dose of tobacco on the control days. But granting this, it is still noteworthy that the one exception among the strictly mental tests in the above table is the very one for which we have been seeking an explanation. This coincidence raises the question at to whether pernicious withdrawal effects may take place in one test, at the same time leaving other tests quite undisturbed? This seems rather unlikely, though perhaps it may be no more remarkable than that one mental function should be stimulated while at

TABLE XXXI

Showing the tendency to gain or loss on the part of the habitual smokers as a possible result of withdrawal of the drug on the control days.

TEST	NON-SMOKERS		HABITUAL SMOKERS		NATURE AND EXTENT OF POSSIBLE NET WITHDRAWAL EFFECTS, HABITUAL SMOKERS	
	Score Pre-dosage Test	Average Score of 3 Post-dosage Tests	Score Pre-dosage Test	Average Score of 3 Post-dosage Tests	Actual Amount of Net Gain or Loss	Percentage of Net Gain or Loss
Tapping	61.9	61.37	63.57	63.48	— .44 (loss)	— .7% (loss)
Reading Reaction-Time	183.36	186.13	190.16	191.23	+ 1.7 (gain)	+ .9% (gain)
Learning Reaction-Time	293.29	295.59	313.14	297.38	+18.06 (gain)	+ 5.8% (gain)
Adding	238.12	242.94	202.07	201.03	— 5.9 (loss)	— 2.9% (loss)
Errors in Adding	3.89	4.24	5.34	4.96	+ .73 (gain)	+13.6% (gain)
Memory Span	8.14	8.11	7.16	7.34	+ .21 (gain)	+ 2.9% (gain)
Learning	11.12	10.68	15.41	13.28	+ 1.69 (gain)	+10.9% (gain)
Average						+ 4.35% (gain)

the same time another is depressed by the same drug and in the same subject.

Turning now to a detailed consideration of the data in question (Table XXX and Fig. 11) we find little evidence of an absolute falling off in the rate of adding during the post-dosage period. The curve is practically horizontal throughout the experimental day, though computation reveals a minute falling off of 1.04 additions per 5-minute period—about ½ of 1 per cent. But during the same period the non-smokers show a *gain* of 4.82 additions. Thus the loss of the habitual smokers (5.86 additions or about 2.9 per cent) is almost entirely a *relative* one. But this does not nearly account for the apparent stimulation of the habitual smokers following the dose on the drug days. An examination of this curve shows that it rises distinctly more than even the control curve of the non-smokers. This rise represents an average gain of 8.91 additions as compared with one of 4.82 for the non-smokers for the post-dosage period. Thus, even under the rather dubious assumption that mental addition would show a pernicious withdrawal effect while all the other mental tests show rather an opposite tendency, approximately half of the apparent stimulation of the habitual smokers is still unaccounted for. But even after making this deduction, the statistical reliability is such that there is still only about 1 chance in 1000 that there is not a real stimulation of adding with these subjects as the result of smoking.

Taking all the available evidence into consideration, then, the indication is quite clear that the smoking of a pipe of tobacco decreases somewhat the adding efficiency of non-smokers but increases that of habitual smokers.

CHAPTER XII

The Effect of Smoking on the Accuracy of Continuous Mental Addition

The technique of the adding test has been fully described in Chapter XI. The score of accuracy in this test was the number of incorrect additions made during each 5-minute period. Errors made but spontaneously corrected by the subject were not counted. At least two types of error may be distinguished: (1) actual incorrect additions, and (2) cases where the wrong digit was added because of momentary confusion as to the sequence of the 6, 7, and 8. The two types appeared to be about equally common though no systematic observations were made on this point. The scoring of the first type was simple. But in cases where two or more apparent errors came in immediate succession, an examination was always made to ascertain whether the subject had gotten out of step in the sequence of the digits to be added. If the additions immediately following were such as to indicate this, the new order was assumed and the following totals were counted as correct, as long as consistent with it, the first addition only of the new series being counted an error.

The detailed scores showing the effect of smoking on the accuracy of mental addition of a typical subject are shown in Table XXXII. The construction of this table and the various computations are exactly as described above, page 39 ff. This subject shows as the result of smoking a loss in efficiency throughout the post-dosage period. On the first post-dosage test the loss attains a satisfactory statistical reliability. The absolute effect is small but the percentage effect is large. The latter is due to the small number of errors made during any 5-minute period.

The final results of the effect of smoking on the accuracy of continuous mental addition is shown in Tables XXXIII and XXXIV for the non-smokers and the habitual smokers respectively. An inspection of the signs in the body of these tables shows at

once that there is no uniformity in the nature of the final averages from the various individual subjects. The final averages from the non-smokers as a group, however, show a tendency to a loss in efficiency as the result of smoking, though in no case does the effect get large enough to attain a satisfactory statistical reliability.

TABLE XXXII

Incorrect addition, subject No. 15, habitual smoker. Score, number of errors made in five minutes of continuous addition.

	Original scores				Difference between normal of day and subsequent tests			
Control days: (Normal)	Test I	Test II	Test III	Test IV	Test II	Test III	Test IV	Average Difference
Nov. 8	15	7	11	7	+ 8	+4	+ 8	+ 6.66
" 10	11	8	9	8	+ 3	+2	+ 3	+ 2.66
" 11	9	9	10	8	0	—1	+ 1	0
" 13	2	7	3	3	— 5	—1	— 1	— 2.33
" 16	8	4	5	1	+ 4	+3	+ 7	+ 4.66
" 18	4	5	2	3	— 1	+2	+ 1	+ .66
" 19	2	1	1	1	+ 1	+1	+ 1	+ 1.00
" 22	3	4	5	0	— 1	—2	+ 3	0
Total	54	45	46	31	+ 9	+8	+23	+13.33
Average	6.75	5.62	5.75	3.87	+ 1.12	+1.00	+ 2.87	+ 1.66
M. V.					2.91	1.75	2.38	2.23
P. E_M					.87	.52	.71	.67
Tobacco days:								
Nov. 7	20	20	17	13	0	+3	+ 7	+ 3.33
" 9	4	18	9	8	—14	—5	— 4	— 7.66
" 12	9	13	6	10	— 4	+3	— 1	— .66
" 14	6	8	9	8	— 2	—3	— 2	— 2.33
" 15	7	9	7	4	— 2	0	+ 3	+ .33
" 17	3	2	2	3	+ 1	+1	0	+ .66
" 20	1	2	2	4	— 1	—1	— 3	— 1.66
" 21	6	2	2	0	+ 4	+4	+ 6	+ 4.66
" 23	4	4	1	3	0	+3	+ 1	+ 1.33
Total	60	78	55	53	—18	+5	+ 7	— 2.00
Average	6.66	8.66	6.11	5.89	— 2.00	+ .55	+ .78	— .22
M. V.					3.11	2.49	5.31	2.54
P. E_M					.88	.70	1.50	.72
Effect of Tobacco:								
Difference					— 3.12	— .45	— 2.09	— 1.88
P. E_D					1.24	.87	1.66	.98
Ratio					2.53	.52	1.26	1.92
Reliability					.9541	.6321	.781	.91
Per cent gain or loss					—46.56	—6.71	—31.19	—28.06

It will be recalled that this set of subjects also showed a loss in the rate of adding. The habitual smokers, on the other hand, average practically zero in effect and the statistical reliabilities are quite negligible.

In addition, the average number of errors made on the various tests throughout both the tobacco and the control days, were computed for both the non-smokers and the habitual smokers. These are shown in parallel curves in Figures 12 and 13 respectively. The marked difference in the points of beginning of each of these

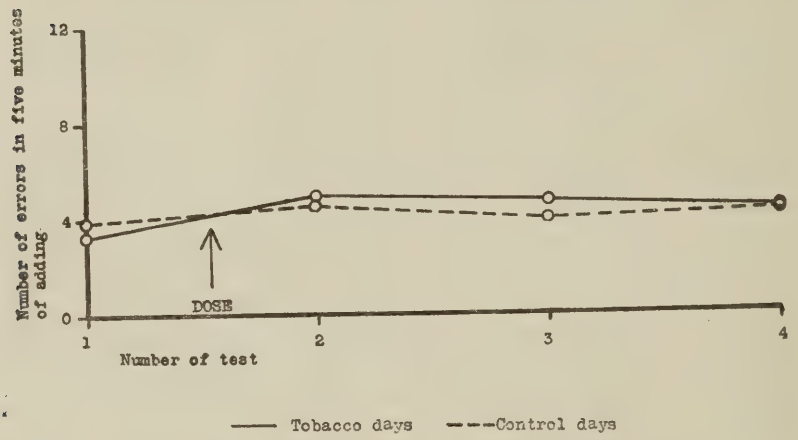

FIG. 12. The effect of smoking on accuracy of adding, non-smokers.

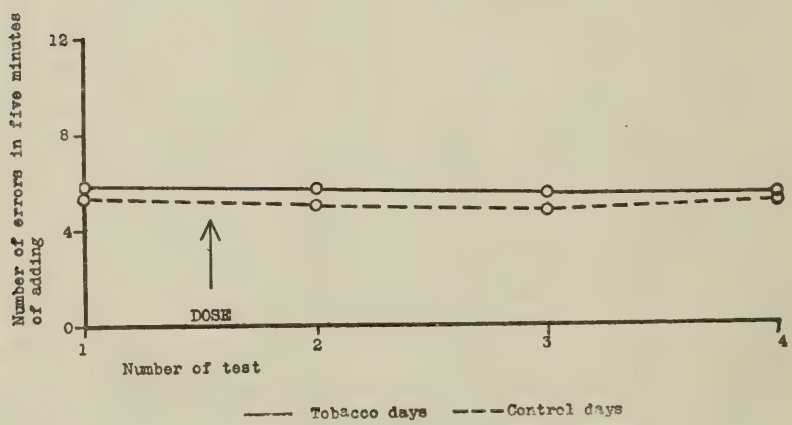

FIG. 13. The effect of smoking on accuracy of adding, habitual smokers.

Table XXXIII

Effect of Tobacco on Errors in Addition, Non-smokers

Score, number of errors made in 5 minutes of continuous addition. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 4.5 min.)				Effect, second post-dosage test (after 39.5 min.)				Effect, third post-dosage test (after 1 hr. 14.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
1	+ .80	.714	.774	+ 53.30	— .40	.766	.637	—26.60	+ .60	.616	.743	+40.00
2	+1.20	.683	.881	+ 44.40	+ .80	.868	.733	+29.60	+2.60	1.070	.949	+ 96.20
3	— .40	.578	.679	— 21.30	+1.60	.673	.944	+85.50	+ .58	.826	.682	+ 31.00
4	+2.00	1.500	.815	+ 47.60	—4.10	1.740	.943	—97.60	—1.70	1.220	.825	— 40.40
5	—2.50	1.560	.859	— 31.60	—3.10	1.670	.893	—39.20	—1.40	2.020	.679	— 17.70
6	+1.00	1.565	.666	+ 22.70	+1.90	.953	.911	+43.60	+ .60	1.293	.623	+ 13.60
7	—1.57	.605	.960	— 70.40	—1.22	1.120	.769	—55.40	+ .33	.758	.614	+ 15.00
8	—2.65	.833	.984	— 77.90	—2.64	.697	.995	—77.60	—2.17	.650	.988	— 63.80
9	—6.52	1.450	.998	—142.00	—4.55	1.730	.961	—99.10	—5.14	1.64	.982	—111.90
Average	**— .96**	1.05		**— 19.47**	**—1.30**	1.14		**—26.31**	**— .633**	1.121		**— 4.22**
M. V.	2.087			54.63	2.041			52.80	1.75			48.20
$P. E._{M}$ (A)	.588			15.39	.575			14.87	.493			13.58
Reliability (A)	**.860**			.80	**.935**			.881	**.800**			.580
$P. E._{M}$ (B)	.351				.378				.374			
Reliability (B)	.966				.990				.870			

TABLE XXXIV

EFFECT OF TOBACCO ON ERRORS IN ADDITION, HABITUAL SMOKERS

Score, number of errors made in 5 minutes of continuous addiition. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 4.5 min.)				Effect, second post-dosage test (after 39.5 min.)				Effect, third post-dosage test (after 1 hr. 14.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	+3.50	1.85	.898	+36.00	+2.90	1.38	.921	+29.90	+1.05	1.69	.662	+10.80
11	—3.50	1.85	.900	—35.10	—4.99	1.63	.980	—50.00	—2.66	1.67	.859	—26.70
12	+1.68	.81	.917	+54.00	+1.38	1.33	.760	+44.30	+1.64	.94	.881	+52.70
13	— .40	1.18	.587	—10.20	+ .23	.93	.567	+ 5.86	+ .87	.98	.727	+22.19
15	—3.12	1.24	.954	—46.56	— .45	.87	.632	— 6.71	—2.09	1.66	.781	—31.19
16	— .57	.98	.635	—11.38	—1.50	1.30	.781	—29.97	— .85	.92	.734	—16.98
17	—1.20	.97	.798	—23.52	—1.30	1.35	.741	—25.49	+1.10	1.07	.756	+21.56
18	+1.29	.57	.936	+39.69	+1.46	.60	.949	+44.92	+ .16	.77	.556	+ 4.92
19	+1.13	.93	.794	+31.74	+ .55	.55	.750	+15.44	+1.42	.87	.864	+39.88
Average	**— .13**	1.15		**+ 3.85**	**— .19**	1.11		**+ 3.14**	**+ .07**	1.17		**+ 8.58**
M. V.	1.31			32.45	1.66			27.71	1.29			23.17
$P.E._M$ (A)	.51			9.14	.47			7.81	.36			6.53
Reliability (A)	**.567**			.606	**.606**			.606	**.553**			**.810**
$P.E._M$ (B)	.390				.370				.390			
Reliability (B)	.593				.632				.540			

pairs of curves suggests a marked variability and, in so far, unreliability of the present data. This is quite in harmony with the striking lack of agreement in the results of the various individual subjects already noticed and with the low statistical reliabilities despite fairly large percentage effects, found in the averages from the group of non-smokers. This is probably due in the main to the small number of error made in any 5-minute period, too small indeed for thoroughly adequate measurement. It should be noticed, however, that both pairs of curves agree in suggesting a general loss in efficiency as the result of smoking though it would be quite impossible to say how much or indeed with any certainty whether it causes any loss at all. The likelihood of a loss in efficiency among the habitual smokers is much less than with the non-smokers.

The only writer who has reported results in errors in addition is Berry. He states that smoking improved accuracy with him, but a recomputation of his results (Appendix F) which eliminated a constant error in them due to practice effects, shows that no effect whatever resulted. This agrees substantially with the results of the habitual smokers in the present investigation.

We may summarize the evidence as to the effect of smoking on the accuracy of mental addition, by saying that there is a little reason to believe that accuracy is slightly lessened with non-smokers but the evidence is quite indecisive in the case of the habitual smokers. If there is an effect among the latter it is too slight to be measured by the present methods.

CHAPTER XIII

The Effect of Smoking on the Auditory Memory Span for Digits

In the last four chapters we have been dealing for the most part with the influence of smoking on the efficiency of the functioning of associative bonds already established. In the present chapter and the following one, our interests shall be directed in the main to the influence of smoking on the ease or rapidity of the original formation of associative bonds. The present one in particular will be devoted to the consideration of the rather short-lived bonds which are established through the single hearing of a digit series, and which are retained little longer than is required to repeat the series orally. It should be noted, however, that the mental process in question is a complex one and that it involves many other factors, among the more important of which are the memory after-image and steadiness of the attention. For this reason it it impossible to say with certainty which of the various factors may be primarily responsible for any effects which may be observed.

The technique of giving the test was very simple. The subject was seated comfortably in a swivel chair about 4 feet in front of the experimenter. After a warning signal, the experimenter began repeating in a loud clear voice at the rate of one a second, a specially prepared series of digits, letting the voice fall on the last of the series. The falling of the experimenter's voice was the signal for the subject to begin repeating the digits so far as possible in exactly the order heard. Ten such trials were given at each test. The score was the number of series out of the ten which were reproduced without error. Spontaneous corrections were permitted. The experimenter was specially trained to give the digits at the right tempo and as an added precaution, he tested himself frequently in this respect by means of a stop-watch which always lay before him while giving the test.

In all, about 300 series of digits were utilized. As a consequence

the use of a given digit series was relatively infrequent, which adequately guarded against any tendency to permanent learning of the material. The series were constructed in the following manner: The 9 digits were written on small cardboard disks which, after thorough mixing, were drawn out at random and written down. All series which chanced to obtain any of the more familiar number progressions such as 2, 4, 6 and the like, were returned to be drawn over. After the 9 digits of each series were recorded, 3 more digits were added at the end of each, making 12 in all. These of course had appeared in the series already. In order that the repetition should appear as little conspicuous as possible, the 3 additional digits were so chosen that they had not appeared either as the first or as the last two of the original series of 9. The various series were typed for use in parallel columns of 10 series each. In order to aid the experimenter's eye, where, as usual, less than 12 digits were being used, vertical lines were drawn in such a way as to separate the eighth digit from the ninth and the tenth from the eleventh.

In order for a test like the present one to succeed, it must be difficult enough so that the subjects will always fail on some of the trials yet easy enough so that they will always be able to get a considerable number correctly. Owing to the marked differences among individual subjects and to the great changes in each subject due to practice, a rather flexible system had to be devised so that these conditions should at all times obtain. Since the results of the first experimental day were always discarded, this day was utilized to discover as accurately as possible the length of digit series that a given subject could repeat correctly about 7 trials out of 10. Suppose this was found to be about 8 digits. Then the subject in question for the following few days, would be given at each test 5 series of 8 digits followed by 5 series of 9. If at the end of 4 days, say, practice had improved his score so that it threatened to exceed the desired limits, the test would be changed to 5 series of 9 digits followed by 5 series of 10. The number of digits in the series was of course always the same throughout any given experimental day. And, while perhaps not absolutely necessary owing to the system of computation, an additional precaution

against possible constant error was provided by the fact that changes from one length of digit series to a more difficult one were always made on a date such that the same number of tobacco and control days had been tested with the length of series about to be discarded. The reason for giving series of two different lengths

TABLE XXXV

Memory span for digits, subject No. 15, habitual smoker. Score, the number of perfect responses out of ten trials.

	Original scores				Difference between normal of day and subsequent tests			
	Test	Test	Test	Test	Test	Test	Test	Average
Control	I	II	III	IV	II	III	IV	Difference
days: (Normal)								
Nov. 8	6	5	9	6	— 1	+ 3	0	+ .66
" 10	3	2	7	6	— 1	+ 4	+ 3	+ 2.00
" 11	2	4	7	4	+ 2	+ 5	+ 2	+ 3.00
" 13	4	6	6	5	+ 2	+ 2	+ 1	+ 1.66
" 16	6	9	4	8	+ 3	— 2	+ 2	+ 1.00
" 18	8	9	8	7	+ 1	0	— 1	0
" 19	6	10	7	8	+ 4	+ 1	+ 2	+ 2.33
" 22	8	8	7	9	0	— 1	+ 1	0
Total	43	53	55	53	+10	+12	+10	+10.66
Average	5.37	6.62	6.87	6.62	**+ 1.25**	**+ 1.5**	**+ 1.25**	**+ 1.33**
M. V.					1.50	2.0	1.00	.92
P. E_M					.448	.598	.299	.275
Tobacco days:								
Nov. 7	7	5	5	8	— 2	— 2	+ 1	— 1
" 9	3	3	4	2	0	+ 1	— 1	0
" 12	5	5	7	6	0	+ 2	+ 1	+ 1
" 14	5	4	3	3	— 1	— 2	— 2	— 1.66
" 15	4	4	8	4	0	+ 4	0	+ 1.33
" 17	9	5	7	3	— 4	— 2	— 6	— 4
" 20	5	7	9	8	+ 2	+ 4	+ 3	+ 3
" 21	7	7	9	7	0	+ 2	0	+ .66
" 23	9	8	8	6	— 1	— 1	— 3	— 1.66
Total	54	48	60	47	— 6	+ 6	— 7	— 2.33
Average	6	5.33	6.66	5.22	**— .66**	**+ .66**	**— .77**	**— .26**
M. V.					1.18	2.15	1.97	1.62
P. E_M					.332	.606	.555	.456
Effect of Tobacco:								
Difference					**— 1.91**	**— .84**	**— 2.02**	**— 1.59**
P. E_D					.56	.85	.63	.53
Ratio					3.42	.99	3.21	2.99
Reliability					.9891	.7392	.9845	.9767
Per cent gain or loss					**—33.62**	**—14.79**	**—35.56**	**—27.99**

at each test was to so widen the range of the test that whatever the effect of the drug, of practice or of accidental factors, the subject would still be able to succeed on some of the trials yet never on all of them, thus conforming to the principles laid down at the beginning of the paragraph.

Lastly, because of the auditory nature of this test, special care was exercised in the choice of subjects, all prospective ones being eliminated who were suspected of being in any way defective in hearing.

The detailed scores showing the effect of smoking on the auditory memory span of a typical subject are shown in Table XXXV. The construction of this table and the various computations are exactly as described on page 39 ff. This subject shows a loss in efficiency throughout the post-dosage period. The differences at two of the three tests show a satisfactory statistical reliability.

The final results of the present investigation are shown in Tables XXXVI and XXXVII for the non-smokers and the habitual smokers respectively. In regard to the individual non-smokers, an inspection of the signs on the first and third post-dosage tests shows a decided preponderance of losses in efficiency as the result of smoking. The final averages from these subjects as a group show a loss in efficiency throughout the entire post-dosage period, the differences on the first and third post-dosage tests attaining a distinctly satisfactory statistical reliability. The individual habitual smokers also show a slight preponderance of losses in efficiency on the first and third post-dosage tests, but less than the non-smokers. Their final averages as a group shows a loss throughout the post-dosage period, particularly on the tests just mentioned though they are distinctly less in amount than with the non-smokers and none of them approach satisfactory statistical reliability. It will also be noted that the second post-dosage test with both groups of subjects shows a decidedly smaller effect than either the first or the third. It will be recalled that this anomaly has been observed on several previous occasions.

The average number of perfect responses on the various tests throughout both the control and the tobacco days was also computed for both the non-smokers and the habitual smokers. These

TABLE XXXVI

EFFECT OF TOBACCO ON MEMORY SPAN FOR DIGITS, NON-SMOKERS

Score, the number of perfect responses out of 10 trials. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 10.5 min.)				Effect, second post-dosage test (after 45.5 min)				Effect, third post-dosage test (after 1 hr. 20.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
1	— .20	.611	.585	— 2.20	+1.20	.868	.823	+13.40	+1.60	.661	.948	+18.00
2	—1.80	.584	.981	—22.70	— .60	.606	.748	— 7.60	— .40	.526	.695	— 5.00
3	+ .86	.604	.830	+11.60	+ .63	.610	.756	+ 8.50	—1.06	.406	.961	—14.00
4	— .10	.602	.543	— 1.20	+ .10	.381	.569	+ 1.20	— .50	.582	.716	— 6.00
5	— .76	.500	.847	—10.60	— .23	.531	.614	— 3.20	—1.60	.522	.980	—22.30
6	— .20	.570	.593	— 2.20	+ .60	.519	.781	+ 6.80	+ .40	.521	.696	+ 4.50
7	— .21	.342	.659	— 2.40	+ .45	.298	.776	+ 5.20	— .54	.397	.820	— 6.20
8	—1.01	.514	.907	—12.00	—2.22	.398	1.000	—26.40	—1.86	.330	1.000	—22.10
9	—1.22	.544	.934	—17.20	—1.78	.588	.979	—25.00	— .736	.673	.768	—10.30
Average	**— .516**	.541		**— 6.54**	**— .205**	.533		**— 3.01**	**— .522**	.513		**— 7.04**
M. V.	.606			8.07	.891			11.14	.708			— 9.00
P. E.$_M$ (A)	.172			2.27	.251			3.14	.200			2.54
Reliability (A)	**.979**			.979	**.710**			.741	**.961**			.970
P. E.$_M$ (B)	.180				.178				.171			
Reliability (B)	.971				.781				.980			

TABLE XXXVII

EFFECT OF TOBACCO ON MEMORY SPAN FOR DIGITS, HABITUAL SMOKERS

Score, the number of perfect responses out of 10 trials. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 10.5 min.)				Effect, second post-dosage test (after 45.5 min.)				Effect, third post-dosage test (after 1 hr. 20.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	—1.65	.51	.985	—24.60	—.30	.54	.644	— 4.47	—1.40	.70	.912	—20.90
11	+1.17	.74	.857	+15.08	—.83	.61	.821	—11.20	+1.67	.77	.927	+ 2.25
12	— .88	.73	.789	—13.10	—.49	.53	.731	— 7.20	—1.33	.77	.877	—19.90
13	+1.67	.57	.976	+22.00	+.34	.42	.705	+ 4.48	+1.66	.61	.967	+21.90
15	—1.91	.56	.989	—33.62	—.84	.85	.739	—14.79	—2.02	.63	.984	—35.56
16	—1.39	.60	.942	—19.78	—.93	.82	.777	—13.19	—1.99	.85	.942	—28.41
17	+ .04	.46	.524	+ .55	+.75	.59	.804	+10.44	+ .15	.81	.551	+ 2.08
18	.34	.58	.652	— 4.54	+.44	.61	.686	+ 5.88	— .09	.62	.540	— 1.20
19	.00	.35	.500	.00	+.71	.47	.846	+ 8.78	+ .81	.50	.863	+10.02
Average	**— .37**	.57		**— 6.37**	**—.13**	.60		**— 2.36**	**— .28**	.70		**— 7.75**
M. V.	.97			14.59	.61			8.67	1.25			16.39
$P. E._M$ (A)	.27			4.11	.17			2.44	.35			4.62
Reliability (A)	**.819**			.852	**.694**			.739	**.705**			.867
$P. E._M$ (B)	.19				.20				.23			
Reliability (B)	.906				.670				.791			

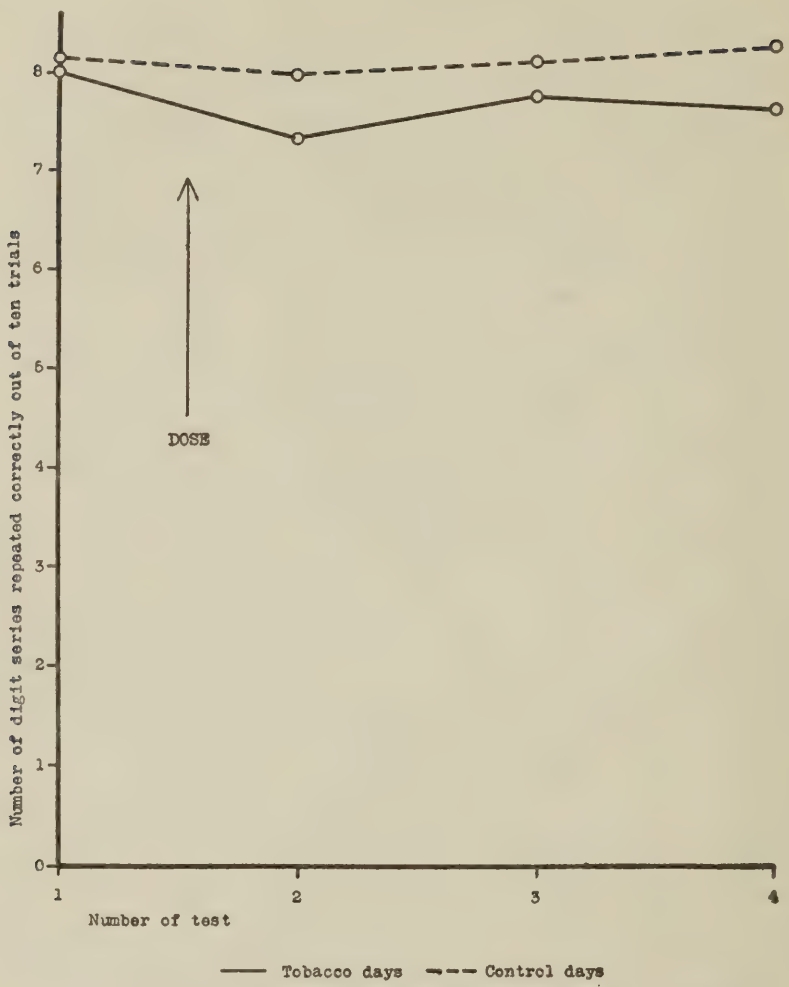

FIG. 14. The effect of smoking on auditory memory span, non-smokers.

are shown in parallel curves in Figures 14 and 15 respectively. The pairs of curves in the two figures resemble each other in a most remarkable manner. In the first place the two curves of each pair originate from practically the same point, the closely similar origin arguing well for the general reliability of the results. What difference there is, in both cases is in favor of the control days. Moreover, in both figures the control curves rise somewhat in the course

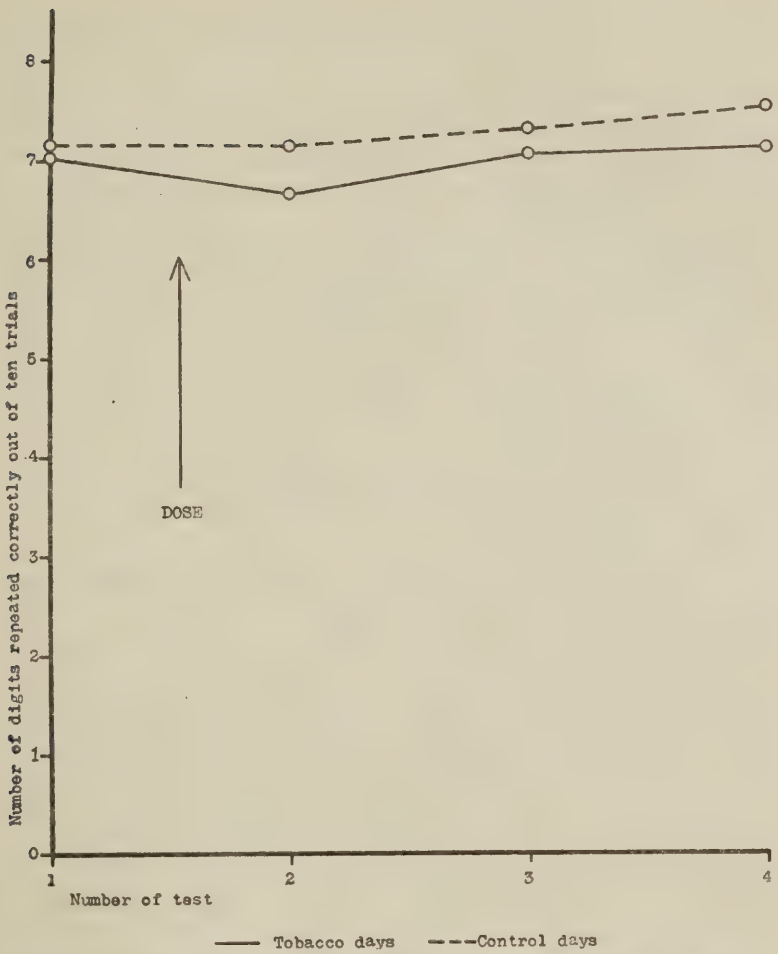

FIG. 15. The effect of smoking on auditory memory span, habitual smokers.

of the experimental day, the rise of the habitual smokers being somewhat greater. Lastly, the drug curves in both cases decline on the first post-dosage test, rise markedly on the second post-dosage test and finally fall again on the last test. The relative levels of the control curves of the two groups of subjects have, in this case no relation to their respective abilities in auditory memory span, since the general level of the score with all subjects was set

more or less arbitrarily by the experimenter as already described (p. 123).

The results of the investigation may now briefly be summarized:

1. The non-smokers show an unmistakable loss in efficiency in memory span as the result of smoking.

2. This is apparently as great 1 hour and 20 minutes after the dose as immediately after.

3. Despite the low statistical reliabilities of the final averages of the habitual smokers as a group, the general similarity of these averages to those of the non-smokers together with the striking similarities of the curves in the two cases, make it quite probable that the habitual smokers as a group show a small loss in efficiency as the result of smoking.

4. Habituation thus appears to have produced a partial tolerance for tobacco in respect to memory span, reducing its effect perhaps something like a half.

5. There is a marked tendency to remission on the second post-dosage test with both groups of subjects.

Two writers have published results showing the effect of smoking on memory span. Froeberg reports the averages from 5 non-smokers on auditory memory span for consonants. He found an average loss in efficiency of about 14 per cent (Appendix G). Bush reports the results of two memory span tests on habitual smokers. One test was by visual presentation and the other was by auditory presentation. In marked contrast to Bush's usually exaggerated effects, these results show losses of only 3 and 4 per cent respectively.

Taking all of the available evidence into consideration, then it becomes quite clear that tobacco produces a detrimental effect upon memory span, at least for those not thoroughly accustomed to its use. Under the conditions of the present experiment, the loss in efficiency ranges around 5 or 6 per cent for non-smokers. The evidence is not quite so clear for habitual smokers. The general indications are, however, that they have a greater tolerance for the drug, showing an average effect, if any, not more than half as great as the non-smokers.

In conclusion a word of caution may not be out of place in

anticipation of a possible hasty and uncritical application of the above results to the ordinary learning process. The fact that the word "memory" appears in the name of the present test does not mean necessarily that we are dealing with the same process that goes by that name in the schools. There are points of resemblance, it is true, and these *may* be the ones upon which the detrimental effects just observed, depend. But the difference between the two processes are much more striking than the similarities. In our present ignorance we cannot say to which the effects are due. Meanwhile we must generalize with caution.

CHAPTER XIV

The Effect of Smoking on the Rate of Learning

In the last chapter we considered the effect of smoking on the facility of the formation of the extremely short-lived associative bonds in auditory memory span. In the present one we shall consider the effect of smoking on the rapidity of the formation of the relatively permanent associative bonds in rote learning. The material memorized consisted, in all, of 360 simple geometrical characters and as many nonsense syllables, one syllable being associated with each character. On any given test, however, only 5 characters with the corresponding syllables were used, because of the necessity for brevity in the test series.[1] About two-thirds of the 360 characters were taken from Moore.[2] The remainder were devised by the present writer. The 360 syllables used were chosen with great care from a list of 2200 specially prepared by the writer for the purpose. In choosing the 5 characters and syllables for any given test series, special care was taken to avoid, so far as possible, characters and syllables which should be confused with each other in the learning. To this end the vowel in the middle of each syllable was different in each of the five as was also the case with the initial consonant and the final consonant. A typical set of characters together with the corresponding syllables is shown in Plate 6.

The mental processes of a subject while doing this test were somewhat like those involved in learning the vocabulary of a foreign language. The necessity for a rigid control of the various factors involved in the process required a rather elaborate technique, though the task of the subject remained simple. The characters were presented to him one at a time, from the window of an automatic exposure apparatus of special design.[3] Exposures were of 5 seconds each and shifts from one exposure to the next

[1] See p. 35 above.

[2] Moore, T. V., The Process of Abstraction: An Experimental Study. *University of California Publications in Psychology,* Vol. I, No. 22, 1910

[3] Hull, C. L., op. cit., pp. 12 and 72.

PLATE 6. A typical set of memory material. The syllables were presented to the subjects vocally. The diacritics indicate the pronunciation used.

were practically instantaneous. Except at the moment of shifting, the character was stationary while being viewed. The window of the apparatus was 1 inch square and well illuminated, though in such a manner as to avoid a glare in the subject's eyes. The syllables to be associated with the respective characters were taught to the subject by a prompting method. In the middle of each 5-second exposure, the experimenter spoke distinctly the syllable to be associated with the particular character exposed, at the same time recording a minus sign in the appropriate part of the special scoring blank provided. The subject repeated the syllable and tried to associate it with the character. Upon the second appearance of a given character, if the subject could recall the associated syllable before the middle of the 5-second exposure (as indicated by the ticking of the clock work of the apparatus) a plus was recorded on the scoring blank and nothing was said. If he made an incorrect response or none at all, he was prompted as at first and given a

minus. The process was continued until the learning was complete. The score was the total number of promptings required.

In order to insure that the associative bonds should be between the individual characters and the particular syllables assigned rather than a mere learning of the syllables in sequence as might easily happen by the usual method of memory experimentation, the 5 characters of a given series were presented to the subject always in 6 different chance orders. Not only this but the order of each of the 72 series of 5's was different from the others. The presentation of each series in 6 different orders was made possible by the fact that over the drum of the apparatus could be placed a long canvas band which hung suspended from it and upon which could be placed a large number of characters. Thirty-six such bands were prepared, each bearing two complete sets of characters. Spurs on one edge of the drum engaged eyelets in the band to insure accurate movements. Moreover, 6 exact photographic duplicates of each character 5/8 inch square were provided. These were attached to the band in the orders indicated, each by a drop of glue. Thus a total of 30 exposures were made before the original order was repeated.[4] By this time the learning was complete in nearly all cases. Accuracy in prompting was secured by a very careful system of key numbers on the scoring blank, corresponding to similar numbers on the band.

The detailed scores showing the effect of smoking on the rate of learning of a typical subject, are shown in Table XXXVIII. These results, while somewhat erratic, show in general a loss in efficiency. The last period shows a satisfactory statistical reliability.

The final results of the present investigation are shown in Table XXXIX and XL for the non-smokers and the habitual smokers respectively. An examination of the signs of the results on the first post-dosage test shows that the great majority of the subjects of both groups show a loss in efficiency as the result of smoking, 22 minutes after its termination. By the second post-dosage test, however, there has ceased to be any general agreement among the subjects. The final averages reflect the same situ-

[4] A second revolution was always made, however, to secure the data on speed of oral reaction to freshly learned material.

ation. The only final average which shows a satisfactory statistical reliability is that of the first post-dosage test of the non-smokers, though the average of the corresponding test with the habitual smokers has a statistical reliability of about 15 to 1. Both averages show a loss in efficiency of about 6 per cent. Because of the simi-

TABLE XXXVIII

Learning, subject No. 15, habitual smoker. Score, number of promptings required to memorize five paired associates of nonsense material.

	Original scores				Difference between normal of day and subsequent scores			
Control days:	Test I (Normal)	Test II	Test III	Test IV	Test II	Test III	Test IV	Average Difference
Nov. 8	8	14	16	8	— 6	— 8	0	— 4.66
" 10	14	28	22	14	—14	— 8	0	— 7.33
" 11	20	10	10	9	+10	+10	+11	+10.33
" 13	8	11	7	10	— 3	+ 1	— 2	— 1.33
" 16	11	14	11	9	— 3	0	+ 2	— .33
" 18	13	15	9	10	— 2	+ 4	+ 3	+ 1.66
" 19	9	7	10	11	+ 2	— 1	— 2	— .33
" 22	18	12	18	17	+ 6	0	+ 1	+ 2.33
Total	101	111	103	88	—10	— 2	+13	+ .33
Average	12.62	13.87	12.87	11	— **1.25**	— **.25**	+ **1.62**	+ **.04**
M. V.					5.44	4.06	2.78	3.55
P. E_M					1.63	1.21	.83	1.06
Tobacco days:								
Nov. 7	28	8	22	24	+20	+ 6	+ 4	+10
" 9	13	20	11	19	— 7	+ 2	— 6	— 3.66
" 12	16	22	17	10	— 6	— 1	+ 6	— .33
" 14	7	9	10	13	— 2	— 3	— 6	— 3.66
" 15	8	17	8	10	— 9	0	— 2	— 3.66
" 17	10	17	14	11	— 7	— 4	— 1	— 4.00
" 20	10	12	14	20	— 2	— 4	—10	— 5.33
" 21	13	9	10	14	+ 4	+ 3	— 1	+ 2.00
" 23	15	18	11	23	— 3	+ 4	— 8	— 2.33
Total	120	132	117	144	—12	+ 3	—24	—11.00
Average	13.33	14.66	13	16	— **1.33**	+ **.33**	— **2.66**	— **1.22**
M. V.					5.93	3.04	4.30	3.41
P. E_M					1.67	.86	1.21	.96
Effect of Tobacco:								
Difference					— **.08**	+ **.58**	— **4.28**	— **1.26**
P. E_D					2.33	1.48	1.46	1.43
Ratio					.03	.39	2.93	.88
Reliability					.513	.606	.976	.729
Per cent gain or loss					— **.61**	+ **4.47**	—**33.00**	—.**9.71**

TABLE XXXIX

EFFECT OF TOBACCO ON RATE OF ROTE LEARNING, NON-SMOKERS

Score, the number of promptings required to memorize 5 paired associates of nonsense material. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 22.5 min.)				Effect, second post-dosage test (after 57.5 min.)				Effect, third post-dosage test (after 1 hr. 32.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
1	+ .40	.383	.758	+ 5.30	— .20	.705	.575	— 2.60	.00	1.00	.000	.00
2	— .20	1.032	.550	— 2.60	— .20	1.509	.532	— 2.60	—1.00	1.18	.714	—12.90
3	—1.50	1.183	.801	—13.60	+3.03	1.130	.965	+27.50	+1.33	1.54	.717	+12.10
4	— .38	1.310	.577	— 2.70	—2.80	2.336	.788	—20.00	+1.20	2.428	.629	+ 8.57
5	—3.68	2.870	.805	—17.70	—1.20	2.660	.619	— 5.80	+ .70	2.730	.567	+ 3.38
6	—1.60	.865	.893	—15.50	— .30	1.550	.550	— 2.90	—1.90	1.370	.823	—18.40
7	+ .48	1.600	.580	+ 5.27	+2.97	1.430	.918	+32.60	+1.19	1.240	.741	+13.07
8	— .94	.642	.838	—16.50	— .50	.369	.818	— 8.70	— .50	.450	.773	— 8.70
9	— .59	1.917	.580	— 4.30	+3.50	1.940	.890	+25.50	+2.60	2.030	.806	+19.00
Average	**— .89**	1.311		**— 6.93**	**+ .48**	1.514		**+ 4.78**	**+ .40**	1.552		**+ 1.79**
M. V.	.924			— 7.911	1.793			15.838	1.102			10.481
P. E.$_M$ (A)	.260			2.229	.505			4.463	.311			2.953
Reliability (A)	**.989**			.982	**.739**			.860	**.800**			.657
P. E.$_M$ (B)	.437				.505				.517			
Reliability (B)	.913				.739				.694			

Table XL

Effect of Tobacco on Rate of Rote Learning, Habitual Smokers

Score, the number of promptings required to memorize 5 paired associates of nonsense material. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject Number	Effect, first post-dosage test (after 22.5 min.)				Effect, second post-dosage test (after 57.5 min)				Effect, third post-dosage test (after 1 hr. 32.5 min.)			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
10	+4.40	2.86	.848	+45.80	+ .44	1.68	.577	+ 5.20	— .21	2.19	.525	— 2.18
11	—8.34	2.84	.976	—30.00	+2.84	4.36	.669	+10.20	.00	4.99	.500	.00
12	—1.86	1.36	.820	—17.50	—3.25	.89	.994	—31.20	—2.46	1.28	.902	—23.30
13	—2.18	2.51	.778	—10.35	+3.57	1.50	.946	+16.95	+2.25	3.21	.682	+10.68
15	— .08	2.33	.513	— .61	+ .58	1.48	.606	+ 4.47	—4.28	1.46	.976	—33.00
16	— .23	1.42	.547	— 2.66	—3.45	1.00	.990	—39.54	—2.68	.91	.975	—30.73
17	—4.78	2.17	.931	—33.85	—1.75	2.10	.722	—12.39	—2.25	2.27	.769	—15.93
18	— .69	3.02	.562	— 3.03	+4.78	2.97	.861	+21.05	+3.69	4.05	.731	+16.25
19	— .17	1.45	.532	— 1.66	—3.48	1.54	.936	—34.05	—2.57	1.87	.824	—25.14
Average	**—1.55**	2.22		**— 5.98**	**+ .03**	1.95		**— 6.59**	**— .95**	2.47		**—11.48**
M. V.	2.44			15.08	2.03			20.19	2.11			15.71
P E_{M} (A)	.69			4.25	.57			5.69	.59			4.43
Reliability (A)	**.935**			.828	**.514**			.781	**.860**			.959
P. E_{M} (B)	.74				.62				.82			
Reliability (B)	.922				.514				.781			

larity of the conditions and results, probably both averages should be considered reliable. All evidence of evil effects have disappeared, however, by the second post-dosage test, 57 minutes after the termination of the smoking.

The average number of promptings required to perfect the learning on the various tests throughout both the control and the tobacco days, was computed for both the non-smokers and the habitual smokers. These are shown by parallel curves in Figures 16 and 17 respectively. It will be noted that the two sets of curves

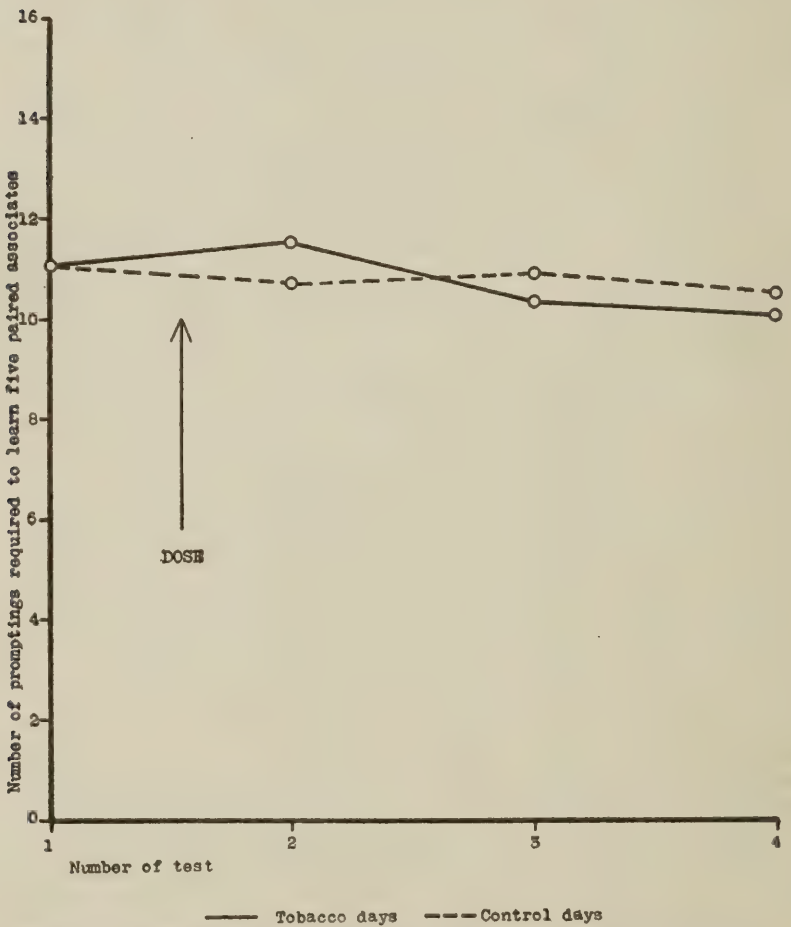

FIG. 16. The effect of smoking on the rate of rote learning, non-smokers.

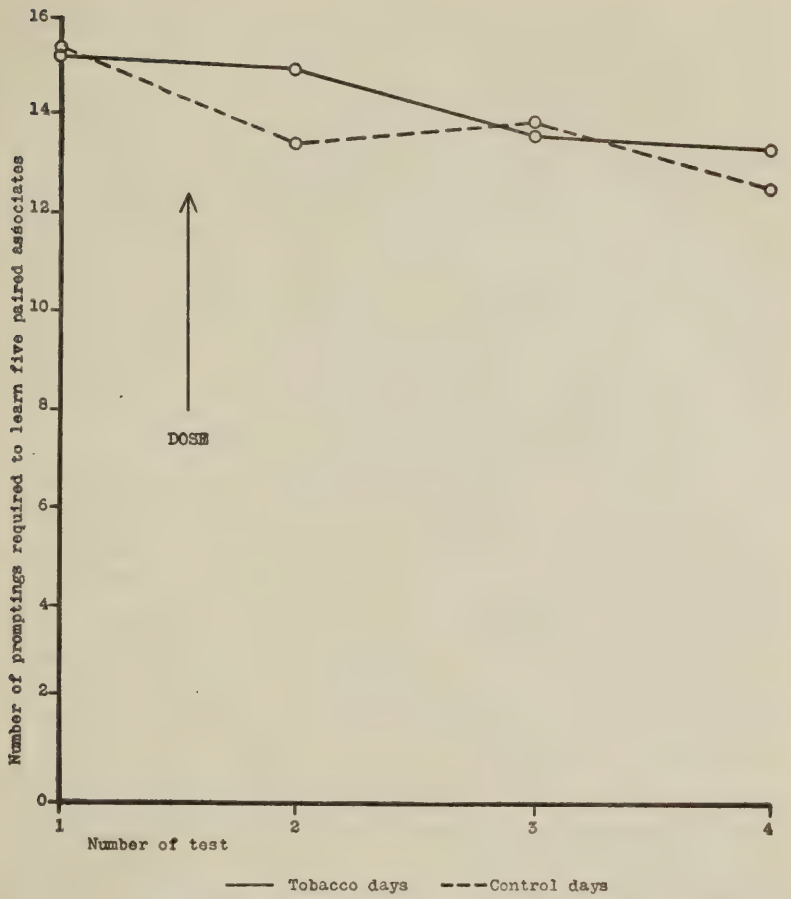

FIG. 17. The effect of smoking on the rate of rote learning, habitual smokers.

show distinct similarities. Both originate at practically the same point. This argues well for the homogeneity of the test material as to difficulty.[5] Immediately after, there is a marked divergence of the curves, amounting to 9 or 10 per cent of the average initial score in each case. This is followed immediately by an approach of the curves on the second post-dosage test, indicating a recovery

[5] In this connection, it should be stated that the test material used on the tobacco and the control days was varied with the different subjects, particularly with the smokers, with the purpose of eliminating any constant error which might chance to exist in the difficulty of the test material.

from the effects, something less than an hour after the conclusion of the smoking. Both sets of subjects show an improvement in the rate of learning in the course of the experimental day, though the improvement of the habitual smokers is more marked than that of the non-smokers. As usual the group of non-smokers average more efficient than the habitual smokers. The difference has a reliability of only .935 so that it is not significant, probably being due merely to the chance sampling of the individual subjects.

The result of the present investigation may now be briefly summarized:

1. The non-smokers show a loss in the rate of learning immediately after smoking, of about 9 per cent.

2. Recovery appears to be complete within an hour.

3. The habitual smokers show an immediate loss in efficiency of about the same proportions, followed also by a recovery within an hour.

4. Habituation in the matter of learning seems, therefore, to have no effect whatever.

5. In the case of the habitual smokers, the tendency to remission of the second post-dosage test noticed frequently in previous chapters, is quite marked. There is also a suggestion of this in the curves of the non-smokers.

Reports of the experimental investigation of the immediate effects of smoking on the rate of learning seems to be entirely lacking from the literature. This is especially to be regretted because of the importance of the question involved, particularly as to its bearing on educational practice. Numerous statistical studies have been found, showing the relation between smoking and school marks, but these studies are quite inconclusive for reasons already given.[6] Our conclusion in this matter must therefore rest entirely on data given above. So far as this goes, the indication is that smoking produces a distinct immediate loss in the efficiency of rote learning, but that recovery is prompt.

[6] See p. 16 above.

CHAPTER XV

Summary and Conclusions

The effects of smoking on the efficiency of the 12 forms of human behavior investigated in the present study have been summarized at the ends of the respective chapters. It remains to assemble these results in a final survey of the investigation as a whole. The final numerical effects on the various functions are accordingly brought together in Table XLI. For purposes of simplicity and general intelligibility, percentage effects alone are given. Numerical reliabilities have been avoided by printing all effects having a satisfactory statistical reliability in special type, and by marking certain other effects which have been judged by the writer as probably reliable but partly upon other than statistical grounds, with a *.[1]

In a similar manner the more important conclusions arrived at in the course of the various chapters may be summarized in a series of formal statements. *These formulations apply primarily to the effects on the habitual smokers,* for it is with the effects on these subjects that practical interest is mainly centered.[2] The list of

[1] It should be noted that the percentage effects shown in this table have been computed in a different manner from those given in the summarizing tables of the various chapters. In the present case the percentages have been computed by dividing the average difference in score produced by the tobacco on the group as a whole, by the average score of the group on the first test of the experimental day. As might be expected, the correspondence between the results by the two methods is very close in most cases. The present method has the advantage, however, of a closer functional relationship to the figure in each case upon which the chief statistical reliability is computed as well as to the data represented by the various curves throughout the preceding chapters. If desired, the interested reader may easily compile for himself a table of the other type of percentages from the final averages of Tables V to XL, as well as one showing the reliabilities, the absolute differences, etc.

[2] It is true that from the point of view of pure science the effects on nonsmokers are as important as those on habitual smokers. Results with nonsmokers also serve an extremely important practical purpose by aiding in the interpretation of the results of the smokers. It is merely implied by the above statement that the effect of tobacco on people who don't use it is not in itself a practical problem.

TABLE XLI

SUMMARY OF THE PERCENTAGE EFFECTS OF SMOKING

*The effects having a satisfactory statistical reliability are given in special type. Certain other effects which have been judged by the writer as probably reliable but partly upon other than statistical grounds, are marked with a *. Plus means a stimulation or gain in efficiency, minus means a loss.*

FUNCTION TESTED		NON-SMOKERS				HABITUAL SMOKERS		
		First post-dosage test	Second post-dosage test	Third post-dosage test		First post-dosage test	Second post-dosage test	Third post-dosage test
Neuro-Muscular Processes	Pulse rate	**+12.63**	**+ 3.07**	**+ 2.74**		**+ 8.09**	**+ 7.25**	**+ 4.52**
	Tremor of hand	**—29.8**	**—31.2**	**—23.2**		**—38.3**	**—22.3**	— 4.8*
	Tapping	+ 1.35	— 1.14	— .39		— 1.4	— .9	+ .5
	Muscular fatigue	**+32.2**	+10.1*	+ 6.2*		**+ 9.6***	**+ 3.7**	—12.5
Sensory-Motor Processes	A-Test, speed	— ?	— ?	— ?		+ .1	— 1.2	— 1.4
	A-Test, accuracy	— ?	— ?	— ?		+22.2	+32.1*	+38.8*
	Reading reaction-time	+ 1.08*	+ .05*	+.54*		+ 1.2*	+ .05*	+ .85*
	Learning reaction-time	+ 4.41*	+ .44*	+ 3.65*		+ .7*	+ .35*	+ 5.55*
Higher Mental Processes	Adding, speed	**— 2.94**	**— 3.43**	**— 2.96**		**+ 3.0**	**+ 4.58**	**+ 6.55**
	Adding, accuracy	—26.5	—36.0	—17.5		— 2.4	— 3.4	+ 1.2
	Memory span	**— 6.38**	— 2.53*	**— 6.46**		— 5.22*	— 1.83*	— 3.95*
	Rote learning	**— 8.02**	+ 4.33	+ 3.61		—10.1*	+ .2	— 6.2

formulations also includes near its end a number of more general conclusions here stated for the first time.

1. There is a marked and uniform stimulation of the heart rate, a considerable amount of which is still present an hour and 40 minutes after smoking.

2. There is evidence of the greater susceptibility of the heart to the influence of excitement after smoking.

3. There is a large and uniform increase in the tremor of the hand. The most of this has disappeared an hour and 23 minutes after smoking.

4. There is probably no uniform effect on the rate of tapping. If such exists it is too slight to be measured by the present methods and number of subjects.

5. The effect on the ability to resist the onset of muscular fatigue is uncertain, though there is a little indication that resistance, at least to a certain type of fatigue, may be increased.

6. There is probably no measurable effect whatever on cancellation. If any exists it is in the direction of a very slight (absolute) gain in accuracy at the expense of an equally slight loss in speed.

7. There is a fair probability of a minute increase in the speed of reading reaction-time, both to old and to recently learned material.

8. There is a marked and uniform gain in the rate of complex mental addition. This stimulation has not begun to decline an hour and 15 minutes after smoking.

9. There is no measurable effect on the accuracy of complex mental addition.

10. There is high probability of a loss in auditory memory span.

11. There is probably a loss in the efficiency of rote learning immediately after smoking, though it is apparently followed by a recovery within an hour.

12. There is no uniformity in the time required for the maximum effects of tobacco to appear with the various tests. The most general statement that can be made on the basis of the present data is that in the case of unfavorable effects the maximum tends

to appear immediately after smoking but favorable effects tend to appear most strongly at the close of the experimental period, roughly 1½ hours after smoking.

13. The influence of habituation on the effects of smoking is, in general, favorable where it has any influence at all. It is noteworthy, however, that with the majority of the processes that show tobacco effects (heart rate, tremor, reading reaction-time, learning reaction-time, rote learning) there is no indication whatever of a tendency for habituation to produce a tolerance.[3] Certain processes (resistance to fatigue, accuracy in addition, memory span) do show a diminution in effect as the result of habituation. In two cases (accuracy in the A-test, complex mental addition) habituation has apparently produced a complete reversal effect.

14. There are numerous indications of a tendency to temporary remission of the ordinary tobacco effects in the period around 50 minutes after smoking, followed by a recurrence of the original effect some 35 minutes later. Superficially this appears to be a kind of rhythm in the action of the drug which, so far as the present writer has been able to discover, is unique in pharmacology. This may be the case. It seems more likely, however, that this tendency to a recurrence of the original effect at the close of the experimental period may be due to a mild excitement on the part of the subjects at nearing the end of the day's work.[4] Owing to the nature of the control methods used in the present experiment, this necessarily requires that the subjects should be more susceptible to this excitement on the tobacco days than on the control days. We have already seen evidence (p. 55) that an effect of exactly this nature exists in the case of heart rate. Moreover, with heart rate it is well known that the effects of the drug and of excitement are identical, which is distinctly suggestive. In the case of the four mental processes showing the tendency to recurrence of the tobacco effect (reading reaction-time, learning reaction-time, auditory memory span, rote learning) the identity of the influence of

[3] This is in marked contract to the rather prompt establishment of a fairly complete tolerance with respect to the well known vomiting reactions common with beginning smokers.

[4] Rivers, op. cit. See p. 24 above.

the two factors of drug action and excitement, while probable, is by no means as certain as with heart rate. In any case the principle of explanation is an interesting one and, if true, may throw light on the nature of the action of tobacco on the higher mental processes. Its obvious relation to the emotions also suggests the possibility of a clue to the charm which tobacco has for those accustomed to its use. Moreover, the well known relation of the emotions to the endocrine glands raises the possibility of a specific action of tobacco upon the latter. But at present the explanation put forward above must be regarded merely as an hypothesis. As such it may be formulated as follows: *Excitement tends in certain mental processes to reinstate tobacco effects where recovery is in progress or has recently taken place.*

In a final review of the various effects of tobacco enumerated above, it will be noted that only three of the 12 forms of behavior investigated reveal an unmistakable influence of smoking. Two of these (pulse, tremor) are essentially physiological. The interest of the present investigation, on the other hand, is primarily in the more strictly psychological processes. Of these, only one (addition) shows an unmistakable effect. Several others show effects with a fair degree of reliability, however, and are entitled to consideration. Probably the two most significant tests of this intellectual group as revealing the influence of smoking on mental efficiency, are complex mental addition and rote learning. The first, together with reaction-time may be presumed to give some indication of the effects of smoking upon ordinary routine thinking, which is essentially the functioning of old associative bonds. The evidence in this case is *favorable* to tobacco where the subject is an adult and is accustomed to its use. Rote learning, on the other hand, possibly supported by memory span, presumably indicates the effect that tobacco is likely to have where new associative bonds are in the process of formation, as in most school learning. The results in this case, while not so reliable, are *unfavorable* to tobacco. It must be remembered, of course, that the above formulations apply with strictness only to the first hour and a half after the termination of the smoking. Generalizations from them must be made with extreme caution.

APPENDIX A

TABLE SHOWING THE EFFECTS OF SMOKING A CIGAR ON HEART RATE AS INDICATED BY COMPUTATIONS FROM J. W. PAYNE'S PUBLISHED DATA.[1]

Subject	BODY IN HORIZONTAL POSITION							BODY IN VERTICAL POSITION						
	Average Heart Rate on Control Days		Gain or Loss After Control Interval	Average Heart Rate on Tobacco Days		Gain or Loss After Smoking Interval	Net Gain or Loss due to Tobacco	Average Heart Rate on Control Days		Gain or Loss After Control Interval	Average Heart Rate on Tobacco Days		Gain or Loss After Smoking Interval	Net Gain or Loss due to Tobacco
	Before Interval	After Interval		Before Dose	After Dose			Before Interval	After Interval		Before Dose	After Dose		
P	76.00	70.0	—6.0	78.40	79.60	+ 1.20	+ 7.20	88.0	81.6	—6.4	80.40	91.6	+11.20	+17.60
R	68.0	62.6	—5.4	64.50	69.50	+ 5.00	+10.40	82.6	82.6	.0	82.00	83.0	+ 1.00	+ 1.00
S	76.8	75.6	—1.2	70.57	73.43	+ 2.86	+ 4.06	78.2	80.8	+2.6	78.57	84.0	+ 5.43	+ 2.83
T	66.8	64.4	—2.4	66.0	71.20	+ 5.20	+ 7.6	85.6	79.2	—6.4	87.20	88.8	+ 1.60	+ 8.00
U	76.8	74.0	—2.8	80.0	80.80	+ .80	+ 3.6	93.6	91.2	—2.4	97.20	102.4	+ 5.20	+ 7.60
V	70.4	71.2	+ .8	72.0	86.8	+14.80	+14.0	81.6	81.6	.0	83.60	98.4	+14.80	+14.80
A	67.0	65.0	—2.0	72.8	80.8	+ 8.0	+10.0	84.0	88.0	+4.0	86.40	96.0	+ 9.60	+ 5.60
B	75.5	72.5	—3.0	76.0	86.0	+10.0	+13.0	90.0	88.0	—2.0	92.0	104.0	+12.00	+14.00
C	62.0	59.0	—3.0	66.0	68.0	+ 2.0	+ 5.0	75.0	76.0	+1.0	85.00	85.0	.00	— 1.00
D	62.0	59.0	—3.0	66.0	68.0	+ 2.0	+ 5.0	75.0	76.0	+1.0	85.00	85.0	.00	— 1.00
Average	70.13	67.33	—2.80	71.23	76.41	+ 5.18	+ 7.98	83.36	82.5	— .86	85.74	91.82	+ 6.08	+ 6.94
P. E.$_M$							.83							1.46
$\frac{D}{P.E._M}$							9.62							4.75
Reliability							1.00							.999

[1] Fisher and Berry, The Physical Effects of Smoking, pp. 1-41.

APPENDIX B

G. A. Dowling's Results on Heart Rate

The results of G. A. Dowling's experiment have briefly been reviewed in Chapter I. Dowling had subjects do strenous jumping after smoking and then counted the pulse the first 15 seconds of each of the first 15 minutes following. A control series was run in which the subject jumped but did not smoke. Fisher and Berry draw certain conclusions from Dowling's results which would be extremely important if true, but which, upon careful examination, seem quite without logical foundation. The present writer has taken the trouble to compute from Dowling's published scores, the average rate for the various smoker subjects for the first, fifth, tenth, and fifteenth minutes after jumping. Where Dowling ceased counting before the end of the 15 minutes, it has been assumed that the pulse continued at the rate given in his last recorded count. The averages in the following table have been computed on this basis rather than (as Dowling did with the non-smokers) on the basis of the few cases which happen to be *above* normal and so got recorded.

It will be seen from the table that the pulse stimulation per minute on the first, fifth, tenth and fifteenth minutes after smoking is 6.0, 8.8, 6.4, and 6.0 beats respectively. Fisher and Berry con-

Subject	SMOKE DAYS					CONTROL DAYS				
	Normal Heart Rate	No. Heart Beats per 15 sec. after smoking and jumping				Normal Heart Rate	No. Heart Beats per 15 sec. after jumping alone			
		1st min.	5th min.	10th min.	15th min.		1st min.	5th min.	10th min.	15th min.
X	79.7	36.6	22.7	23.2	22.7	88.0	36.4	22.2	22.2	22.0
Y	78.9	34.5	19.9	19.7	19.8	80.0	35.8	20.6	21.0	21.0
Z	72.2	38.3	20.2	20.2	19.9	78.8	36.6	20.0	19.8	19.8
M	76.5	35.2	21.6	19.9	19.8	71.4	35.4	18.0	18.0	18.0
N	80.2	39.2	21.3	20.9	21.3	73.8	34.6	18.8	18.6	18.6
T	89.2	37.0	26.8	26.8	26.5	85.8	32.0	22.8	21.6	21.6
W	86.6	35.3	22.4	22.5	22.5	85.8	34.8	21.4	21.2	21.2
Average	80.5	36.6	22.7	21.7	21.8	80.5	35.1	20.5	20.3	20.3
Per min.	80.5	146.4	90.8	87.6	87.2	80.5	140.4	82.0	81.2	81.2

clude from Dowling's results that smoking delays the recovery of the heart from a stimulation which is the result of exercise. As a matter of fact all the results prove is that the ordinary stimulation due to smoking persists relatively undisturbed by the jumping, for at least 15 minutes. Surely, the jumping had nothing to do with this, for our own results have shown that the pulse has by no means returned to normal after nearly 2 hours where there was no jumping whatever. The experiment should have been set up quite differently to make a solution of Dowling's problem possible.

Fisher and Berry also conclude from Dowling's results that smokers have a normal heart rate higher than non-smokers. The present writer has averaged the pre-dosage rate for both the control and the tobacco days for each subject of the two groups. They appear in the following table:

	SMOKERS	NON-SMOKERS		
	83.9		Difference	2.4
	79.5	82.3		
	75.5	82.3	P. $E._D$	2.19
	74.0	80.5		
	77.0	88.9	Ratio	1.09
	88.3	68.1		
	87.5	77.7	Reliability	
	86.2	73.8	of	.770
	—	—	difference	
Average	81.5	79.1		
P. $E._M$	1.49	1.61		

It will be seen that the averages show a slightly higher rate for the smokers, but a computation of the statistical reliability of this difference shows that a difference as large as this would under the present circumstances happen by pure chance in about 2 cases in 10. Such a statistical reliability is of course far below the lowest limit ever accepted in scientific work. Fisher and Berry's generalization is therefore quite unwarranted.

APPENDIX C

Warren P. Lombard's Results on Muscular Fatigue

The results of Lombard's investigation of the effects of tobacco on muscular fatigue have been reviewed in Chapter I. His published results are summarized in the following table:

CONTROL DAYS		TOBACCO DAYS	
Date	Amt. of work in Kgrm.	Date	Amt. of work in Kgrm.
March 6	11.25	March 2	15.00
" 7	15.15	" 3	11.31
" 8	18.69	" 4	8.79
" 12	19.02	" 5	8.04
		" 9	13.71
		" 10	12.48
		" 11	10.29
Average	16.027		11.374
P. E_M	1.193		.645

Difference	4.653 Kgrm. in favor of the control days
P. E_D	1.356
Ratio	3.43
Reliability	.989

APPENDIX D

Vaughan Harley's Results on Muscular Fatigue

The result of Harley's investigation of the effects of smoking on muscular fatigue have been reviewed in Chapter I. His published results are summarized in the following table. This shows the average gain or loss as the result of smoking from six experiments. A plus in Harley's published results means that the control performance was more efficient than the drug performance.

	No. Kgrm. gained or lost as result of smoking	No. seconds gained or lost in resisting fatigue as result of smoking
	+1.876	+72
	—1.736	—27
	+1.010	+26
	+1.795	—40
	+ .851	+ 8
	— .450	—10
Average =	+ .558	+ 4.80
P. $E._M$ =	.380	10.40
Ratio =	1.470	.46
Reliability =	.836	.62

APPENDIX E

Theodore Hough's Results on Muscular Fatigue

The results of Hough's investigation of the effects of tobacco on muscular fatigue have been reviewed in Chapter I. His rather meagre published results are summarized in the following table:

CONTROL DAYS		TOBACCO DAYS	
Date	Diff. between before and after control interval	Date	Diff. between before and after smoking
May 8	+ 70	May 7	+ 90
" 9	+110	" 21	+240
" 15	—140		
" 23	— 30		
Average	+ 2.50		+165
P. E.M	37.00		44.8

Net difference = 163.5 sec. in favor of the tobacco days
P. E.D = 58.1
Ratio = 2.81
Reliability = .971

APPENDIX F

C. S. Berry's Results in Adding

Charles Scott Berry's results regarding the effect of smoking on adding have been reviewed above, Chapter I. The significant part of his published table of results is reproduced below. Since his tobacco days are in all cases one day later than his control days and hence have the advantage of one day's practice effects, the difference which he finds between the averages of the two sets of days in reality are a compound of tobacco effects and practice effects. In order to eliminate these practice effects, the present writer has computed for each tobacco day the amount of gain in speed over the average speed of the day immediately preceding it and the day immediately following it. This has been done on the assumption that the average of these two days will give, on the long run, the approximate non-drug speed of the tobacco days had tobacco not been used. This difference, then, should give us the approximate tobacco effect undisturbed by practice. Since there is no control day following the last tobacco day, the last entry of our column of effects was obtained by finding the difference between the last control day and the average of the tobacco days immediately preceding and following it.

Berry's computations show a gain of .5 of a point in accuracy and of 90 seconds in speed. These are gains of 4.5 per cent and 7.7 per cent respectively over the non-smoking days. When practice effects are eliminated as indicated above, the .5 gain in accuracy becomes practically zero and the 90 seconds gain in speed to 70.7 seconds or 6.1 per cent. The statistical reliability of the effect on speed is extremely satisfactory.

APPENDIX G

Summary of Froeberg's Results[1]

This table reproduces Froeberg's tabular summary of his second experiment. In addition the reliabilities of the results of the individual subjects, the percentage effects and the statistical reliabilities of the group averages have been supplied by the present writer. Plus means a gain in efficiency as result of smoking, minus means a loss.

Subject	MEMORY				FREE ASSOCIATION				ADDITION				OPPOSITES				COMPLETION			
	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss	Gain or loss	Probable error	Reliability	Per cent gain or loss
Bu	—14.00	6.10	.939	—23.40	—6.30	2.00	.983	—15.60	—2.60	4.40	.857	— 4.10	+ .60	.60	.750	+ 3.40	1.51	2.54	.657	—
H	—14.00	6.30	.931	—20.00	—3.00	1.10	.966	— 9.40	+1.80	1.00	.889	+ 3.60	—1.90	.40	.999	—11.30	.92	1.20	.693	—
P	—24.00	3.80	1.000	—37.00	—7.80	2.80	.970	—17.40	—4.20	2.30	.890	— 7.70	—1.20	1.20	.750	— 6.00	.37	1.33	.580	—
R	—13.20	5.10	.960	—25.50	—3.50	1.80	.905	—15.20	—1.80	2.20	.705	— 4.00	— .30	.80	.593	— 2.20	.12	3.31	.513	—
W	+16.80	6.40	.960	+38.10	—1.80	.80	.935	— 7.80	—6.10	3.80	.859	—17.40	— .60	.40	.844	— 5.00	2.29	1.74	.809	—
Average	**— 9.68**	5.54		**—13.56**	**—4.48**	1.70		**—13.08**	**—2.58**	2.74		**— 5.92**	**— .68**	.68		**— 4.22**	**1.04**	2.02		
M. V.	10.59			20.66	2.06			3.58	2.06			5.30	.69			3.85	.68			
P. E_M (A)	44.00			7.81	.78			1.35	.78			2.00	.26			1.46	.26			
Reliability (A)	**.950**			.88	**1.00**			1.00	**.987**			.977	**.960**			.974	**.996**			
P. E_M (B)	2.48				.76				1.23				.30				.90			
Reliability (B)	.996				1.00				.920				.934				.781			

[1]Journal of Experimental Psychology, Vol. 3, p. 334 ff.

Day	Reproduction of Berry's Table				Tobacco effects after correction for practice	
	Errors		Time in min. and sec.		Errors	Time in sec.
	Smoking	No smoking	Smoking	No smoking		
1	—	22	—	23:50	—	—
2	12	—	21:30	—	+4.5	+73.5
3	—	11	—	21:37	—	—
4	10	—	19:38	—	—0.5	+68.0
5	—	8	—	19:55	—	—
6	18	—	18:45	—	—3.5	+50.0
7	—	21	—	19:15	—	—
8	15	—	18:10	—	.0	+66.0
9	—	9	—	19:17	—	—
10	5	—	18:3	—	+3.0	+54.0
11	—	7	—	18:37	—	—
12	10	—	17:23	—	—2.5	+70.7
13	—	8	—	18:30	—	—
14	8	—	16:23	—	—0.5	+98.5
15	—	7	—	17:33	—	—
16	14	—	15:50	—	—5.0	+89.5
17	—	11	—	17:6	—	—
18	6	—	16:27	—	+4.0	+56.0
19	—	9	—	17:40	+1.0	+81.0
20	10	—	16:11	—	—	—
Average	10.8	11.3	17:50	19:20	+ .05	+70.7
P. E.$_M$						3.20
Ratio						22.10
Reliability						1.00

APPENDIX H

Baumberger and Martin's Results

The investigation of Baumberger and Martin as to the effect of smoking on the efficiency of telegraph operators has been reviewed in Chapter I. These writers make a commendable effort at a statistical evaluation of their results. Unfortunately they used an erroneous method of computation with the result that their final conclusions are largely unwarranted by their facts. They state quite truly "that differences between means to be significant must contain the probable error twice and should contain it three times. . . ." They made the mistake, however, of taking as the probable error of the difference (P. $E._D$) the average of the probable errors of the two means from which the difference was obtained. As a matter of fact the probable error of the difference between two means, is the square root of the sum of the squares of the probable errors of the two means.

The formula is:[1]

$$P.E._D = \sqrt{P.E._{M_1}^2 + P.E._{M_2}^2}$$

Naturally the probable error of a difference is a much larger figure than the average of the probable errors of the two means. It is because of this that Baumberger and Martin in a number of cases report as reliable drug effects, what in reality may be nothing more than the result of chance errors of sampling. The following table is largely a reproduction of a table published by Baumberger and Martin showing their results and method of computation. The present writer has made the appropriate computations from Baumberger and Martin's figures by the approved formula and the results are given in adjoining columns. It will be seen at a glance that the computed ratios are much smaller than those given by Baumberger and Martin, and only two of the nine attain a satisfactory degree of reliability.

They do not state how they computed the probable errors of

[1] Thorndike, E. I., Mental and Social Measurements, p. 193. Whipple, G. M., Mental and Physical Tests, p. 27.

BAUMBERGER AND MARTIN'S TABLE							CORRECTED RESULTS	
Hour of day	Rate for Heavy Smokers		Rate for Light Smokers		Difference	Ratio of Difference to Average Probable Error	P. E.$_D$	Ratio of difference to the Probable Error of the Difference
	Mean	P. E.$_M$	Mean	P. E.$_M$				
1	37.80	±0.91	28.48	±1.62	—9.32	—7.3	1.86	5.00
2	45.02	±1.66	48.21	±2.36	+3.19	1.5	2.89	1.10
3	42.25	±1.25	43.30	±2.02	+1.05	0.6	2.37	.44
4	38.77	±1.14	43.00	±1.57	+4.33	3.1	1.94	2.23
5	38.98	±1.14	44.75	±2.12	+5.75	3.5	2.41	2.39
6	31.64	±1.08	40.00	±2.20	+8.36	5.0	2.45	3.41
7	39.10	±1.50	33.92	±2.30	—5.18	—2.7	2.75	1.88
8	38.50	±1.95	41.50	±2.50	+3.00	1.3	3.17	.94
9	29.80	±1.60	37.50	±2.74	+7.70	3.5	3.18	2.42
Average	38.00	1.358	40.07	2.159	2.09			

their means. There are some indications that this may also have been done by an incorrect method. The present writer has computed the entire set from the standard deviations which are published. In almost every case the computation yields much larger probable errors than Baumberger and Martin give. Those from heavy smokers average 1.80 and those from the light smokers average 2.66. When the P. E.$_D$'s are computed from these probable errors, the rations become still less than those shown in the last column of the above table. For example, the one for the sixth hour which by the above table is still above 3, shrinks to 2.64.

It is impossible to determine in a wholly satisfactory manner from their published data the reliability of the final average difference between the light and heavy smokers for the day as a whole. A fair approximation to it may be obtained by taking the average probable error of the hourly means as the probable error of the average hourly rate for the respective groups. This method yields a probable error of the difference between the day's output of the two groups, of 2.55, whereas the difference itself is only 2.09. This gives a ratio of .81 which corresponds to a reliability of .710 which is quite negligible. Their results are accordingly quite indecisive as to the relative total daily output of light and heavy smokers.

APPENDIX I

Meylan's Results on Smoking and Scholarship

The investigation by George W. Meylan of the effect of smoking upon university grades has briefly been reviewed in Chapter I. Meylan concluded that the relation between smoking and scholarship was so complicated by other factors that it was impossible to tell whether tobacco had any real causal effect or not. As a matter of fact the situation, while complex, yields quite readily to mathematical analysis. The present writer has taken the trouble to make the necessary computations from Meylan's published results and the various operations and results are indicated below. Unfortunately Meylan's tables do not always supply the necessary information in exactly the form that is desired, which has necessitated a certain amount of interpolation. For this reason as well as by reason of the small number of data, the result of this computation are not to be regarded as having any considerable reliability. They are given rather as an illustration of a method which may be employed in the investigation of this extremely important problem. The data upon which the following computations are based, appear in the following table.[1]

Since the analysis is to be accomplished by means of partial correlation, it is first necessary to secure all the correlations of zero order among the four variables. The ordinary product-moments method can not be used here because of the all-or-none nature of many of the variables. The coefficients may be computed quite

[1] The figures in the two columns under "scholarship" were in all cases derived from Meylan's published tables showing the average of the marks of the various groups. It was assumed in these computations that 1 point in school marks corresponds approximately to .12 of the standard deviation of the distribution of the grades in any given group (D. Starch, Educational Psychology, p. 442). Assuming a normal distribution it is easy by means of a probability frequency table to tell approximately the number of men of one group falling above or below the median of another group, once the difference in average mark is known.

			SCHOLARSHIP		SMOKING		FRATERNITIES	
			Number of men falling below the average of the better group	Number of men above the average of the better group	Number of Smokers	Number of Non-Smokers	Number of Fraternity men	Number of Non-Fraternity men
SMOKING	Number of Smokers	115	92	23				
	Number of Non-Smokers	108	54	54				
FRATERNITIES	Number of Fraternity Men	66	58	8	49	17		
	Number of Non-Fraternity Men	157	79	78	66	91		
ATHLETICS	Number of Men who Made Athletic Teams	84	61	23	47	37	41	43
	Number of Men who did not make Athletic Teams	139	70	69	68	71	25	114

readily, however, by means of the four-fold table method. The formula used in the present computation was:[2]

$$r_t = \cos \frac{\sqrt{bc}}{\sqrt{bc} + \sqrt{ad}} 180^\circ$$

If sufficient data were available to yield really reliable results, Pearson's more accurate method should, of course, be used. With

[2] Whipple, G. M., Mental and Physical Tests, Simpler Processes, p. 48.

the aid of special tables now available[3] the labor of computation by Pearson's method is no longer excessive.

The various correlations of zero order resulting from these computations appears in the following table:

	Poor Scholarship	Smoking	Fraternities
1. Poor Scholarship			
2. Smoking	+.50		
3. Fraternities	+.66	+.50	
4. Athletics	+.36	+ .11	+.53

It is next necessary to determine what the correlation between smoking and poor scholarship alone would be, if the influence of fraternities and athletics on scholarship were eliminated. This is accomplished by means of partial correlation. The formula is:[4]

$$r_{12.3} = \frac{r_{12} - r_{13} \times r_{23}}{\sqrt{1 - r^2_{13}}\ \sqrt{1 - r^2_{23}}}$$

The final result is accomplished by a series of applications of the formula resulting in successive eliminations. The results obtained at the various stages of the process are as follows:

Correlation, poor scholarship and smoking, athlectics constant..... +.49
Correlation, poor scholarship and fraternities, athletics constant..... +.59
Correlation, smoking and fraternities, athletics constant ..... +.52
Correlation, poor scholarship and smoking, both athletics and fraternities constant ..... +.27

The last entry in the above series gives us what we are seeking. It shows that the correlation between poor scholarship and smoking is reduced from +.50 to +.27 or approximately half, when the influence of athletics and fraternities are eliminated.

It is also a matter of some interest to know what the difference between the averages of the marks of the two groups would be

[3] Pearson, Carl, Tables for Statisticians and Biometricians, p. 42 ff.
[4] Yule, G. U., Introduction to the Theory of Statistics, p. 239.

with the influence of athletics and fraternities removed. By substituting appropriately in the above correlation formula it is found that under the new conditions 77 of the smokers would fall below the median non-smoker or 15.8 per cent more than would if the two groups were of equal scholarship. This amounts to .41 of the standard deviation of the grades of the groups. Assuming .12 of the standard deviation to correspond to 1 point in school marks, this deviation would correspond to a difference between the two groups in average standing, of 3.4 points.

APPENDIX J

The following table summarizes the results of subject No. 14, an habitual smoker. This subject discovered the control and his results were not considered reliable. They have therefore not been included in the general report. They are given here for the sake of completeness.

FUNCTIONS TESTED	TOBACCO EFFECT FIRST POST-DOSAGE TEST		TOBACCO EFFECT SECOND POST-DOSAGE TEST		TOBACCO EFFECT THIRD POST-DOSAGE TEST		TOBACCO EFFECT FOURTH POST-DOSAGE TEST		AVERAGE FOR ENTIRE PERIOD	
	Amount	Per cent	Amount	Per cent	Amount	Per cent	Amount	Per cent	Amount	Per cent
Heart rate	— .29	— .38	— .56	— .73	— .41	— .53	—2.58	—3.36	— .97	— 1.26
Tremor of hand	+11.08	+32.06	+ 1.69	+ 4.80	+ 5.00	+14.40			+5.41	+15.60
Rate of tapping	— .46	— .90	— .46	— .86	— 1.93	— 3.60			— .96	— 1.80
Muscular fatigue	— 1.47	—45.20	+ 1.65	+50.70	+ .76	+23.40			+ .31	+ 9.50
Speed on A-test	+ 1.98	+ 2.30	— .08	— .09	+ 3.51	+ 4.10			+1.81	+ 2.10
Accuracy, A-test	+ .41	+14.00	+ 1.41	+50.00	+ 1.69	+59.90			+1.17	+41.40
Reading reaction-time	— 3.09	— 1.70	— 5.45	— 3.00	— 9.11	— 5.10			—5.88	— 3.28
Learning reaction-time	+27.33	+ 9.30	—13.43	— 4.50	— 9.91	— 3.40			+ .12	+ .04
Rate of addition	+ 4.97	+ 4.27	+ 1.77	+ 1.52	—13.88	—11.90			—2.38	— 2.04
Accuracy of addition	+ .68	+24.00	+ 1.97	+69.60	+ .77	+27.20			+1.13	+39.90
Auditory memory span	— .10	— 1.20	— .58	— 6.80	— 1.60	—19.70			— .78	— 9.20
Rate of learning	+ 6.38	+49.23	+ 3.83	+29.55	+ 1.97	+15.20			+4.06	+31.33

APPENDIX K

ARYFRNJLVAABAHPYKKQAKPALEWNAIPAAEHANAO
AZQUWBIJXAGLONDSEMRAJYQAFAVUYADOAYADCWA
AFRAAKUATAAAWCFZAAUDFEHMSLBAXBACZJOVAW
IUMUYZXAJFDGKTOFFSAOCLAMVYVASDZAJAIATBAC
AGYHUZSHRGQJTNAPJRWOPQDCMAUEEIMNXDGTAQ
AMUIXATOPOGCTNVAGXKAARCADAHDQBAFXLDWYI
RWXBGXBIUQADSJNMPAGAVAWIYZMXMNZTEAAAZA
MAHHMGKPIAAWCGNSWALTQRYAKCGDXKSTAVUXX
KLPVAOYAASQLRVXISOADSYTVILPAOVJUAENNJLKP
SPOULVRBJQUANAAJHFBIQGHVAVENAICIPRENTELA
AAWBGNWSQRXOXGOCHPSQUQWBLARRAZAZIEMDT
APKNKBCAJZPBSLRJHHEASFFTNAVBWZAEAAALEWA
HCRVASTYWALAUVGFKEADHOFABQKCTAFAYNCWHA

Name..... Date.....

Test No..... Score.....